NASA CONTRACT NAS 2-6518

HEUS-RS APPLICATIONS STUDY

FINAL REPORT - VOLUME I

D2-116262-1

SUBMITTED TO:

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SEATTLE, WASHINGTON

ABSTRACT

This document is a final report of a High Energy Upper Stage - Restartable Solid (HEUS-RS) Applications Study, NASA Contract NAS 2-6518. The material herein deals with sizing and integrating a high energy upper stage restartable solid motor into a flight stage with various payloads for use with Titan III and Thor launch vehicles. In addition, performance of the HEUS-RS with the space shuttle is briefly examined.

KEY WORDS

Titan IIIB
Thor
Thorad
Centaur
HEUS-RS
Total Impulse
Specific Impulse
Propellant
Quench
Performance
Mission Model
Space Shuttle

ABBREVIATIONS AND ACRONYMS

BII	Burner II
ΔV	Delta Velocity
ETR	Eastern Test Range
FCE	Flight Control Electronics
GRU	Gyro Reference Unit
HEUS	High Energy Upper Stage
HEUS-RS	High Energy Upper Stage-Restartable Solid
RCS	Reaction Control Subsystem
ROM	Rough Order of Magnitude
TAT	Thrust Augmented THOR
WTR	Western Test Range

Volume I

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1.0 INTRODUCTION AND SUMMARY

1.1 INTRODUCTION

This report presents the results of a Restartable High Energy Upper Stage Applications study conducted for NASA under the technical direction of Jet Propulsion Laboratory, Contract NAS2-6518. The objectives of the study were:

1. Analyze the mission performance capability of a restartable "High Energy Upper Stage" and determine the optimum restartable solid motor size that will provide NASA the most capability in meeting the mission class requirements when it is incorporated into the mission model.

2. Provide a conceptual configuration of a potentially high usage "High Energy Upper Stage" using a restartable solid motor (HEUS-RS).

3. Evaluate and compare the effect of restartable "High Energy Upper Stages" on launch program performance and cost.

Previous studies have shown significant payload performance gains when stop/re-start was incorporated into solid rocket motors. The most significant advantage of re-start capability is realized when used in the upper stage of two stage launch vehicles where the second burn of the upper stage can be used for apogee injection and/or the injection of more than one payload in different orbits. Appropriate application of this capability will preclude usage of more expensive multi-stage vehicles and result in total launch program costs.

The results of the study are contained in two volumes. This document, Volume I, contains the launch program definition, restartable motor definition and upper stage configuration, performance analysis and launch program evaluation. Volume II contains the cost data. During the course of the study four interim reports were made and they are listed as Reference 1, 2, 3, and 4 in Section 3.0 of Volume I.

This study originally consisted of six tasks. Task 1 through 5 were technical study tasks, Task 6 was assigned for reporting only. As the study progressed revisions were made to the task assignments, with some items deleted and Task 7 added.

1.2 SUMMARY

1.2.1 Background

Restartable solid motors have been studied by NASA and a feasibility demonstration motor was fired successfully in 1970. Preliminary analysis indicates the most significant advantage of restart capability is realized when used in an upper stage where the second motor burn can be used for apogee injection and/or the injection of more than one payload into different orbits.

The re-startable solid motor fired by NASA incorporated high performance propellant containing a Beryllium additive to the propellant which increased the specific impulse.

This study considered only Aluminum added to the propellant mixture with a related I_s of 303 seconds.

1.2.2 Scope

This study was divided into seven tasks, six technical and one reporting. The work covered in each of the tasks is as follows.

Task 1 - Review the NASA mission model and separate it into four mission classes; Low Earth Orbit, Synchronous, Earth Escape, and Planetary Orbiter. Determine the number of launches for each mission class. These will be used for cost comparison in later tasks.

Task 2 - Perform preliminary performance trades for the mission. Mission classes and boosters listed in Task 1 were used to determine required single and multi-burn times and ΔV required to permit HEUS-RS sizing. Design "rubber" HEUS-RS stage configurations for each booster and mission class. Select optimum motor size and design an upper stage that has highest usage rate.

Rask 3 - Perform a mission analysis using the HEUS-RS configuration and determine payload in orbit and trajectory data. Determine the total HEUS-RS launch program ROM cost. Determine a separate ROM cost for development and qualifications of HEUS-RS including launch vehicle and launch site integration.

Task 4 - Determine the total launch program ROM cost to perform the bulk of the mission flights generated in Task 1 mission model.

Task 5 - Compare the costs of Task 3 and 4.

Task 6 - Reporting, reviews, and documentation.

Task 7 - Determine the ability of the HEUS-RS/BII to perform and meet shuttle mission requirements.

During the course of the study, as results became known, changes to the original study outline were recommended and authorized. Some original study tasks were deleted and new tasks were added. These changes include the deletion of Air Force missions from Task 3, the replacement in Task 4 of the alternate launch concepts with launch vehicles and costs generated by Battelle Memorial Institute, the deletion of comparing the performance capability of Task 3 and 4 launch programs, and the addition of Task 7 HEUS/BII Shuttle Application.

A study flow diagram showing work performed under each task and the above mentioned study deletions and additions is shown in Figure 1.2-1.

HEUS STUDY

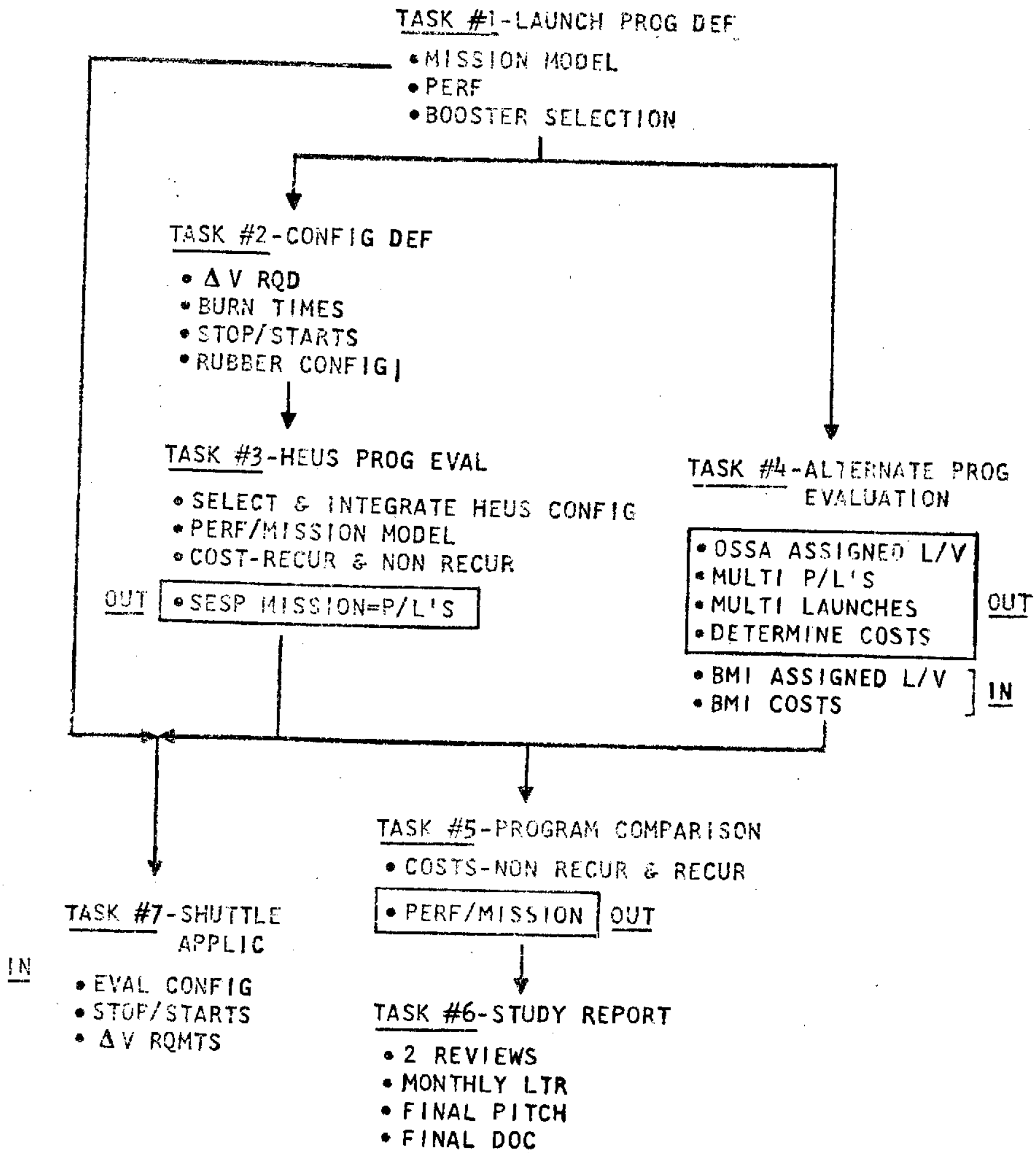


FIGURE 1.2-1

1.2.3 SUMMARY

1.2.3.1 Launch Program Definition

The mission model provided at the beginning of the study was modified to reflect all available data on the missions listed. These modifications included launch vehicle assignment, revised mission data and deletion of missions where inadequate data, for the purposes of this study, were available.

Assignments of launch vehicles, where none were shown, were based on the NASA Launch Vehicle Estimating Facotrs books 1971 and 1972 (Reference No. 6 and 7). In cases where mission requirements could not be met with the vehicle assignment given, revised assignments were made.

The mission model includes low earth orbit, synchronous equatorial and escape missions. The study results show that the prime requirement for a restartable solid is the low earth orbit missions.

Evaluation of the mission model was accomplished with the HEUS stages in combination with the Thorad, Titan IIIB and Titan IIID. No appropriate applications were found for the HEUS with Delta or Centaur. The Delta and Centaur already offer a restart capability and the additional restart of HEUS provides no increased capability over a non-restartable solid motor.

1.2.3.2 Task 2 Summary

Payload capability was evaluated for three motor sizes, 3000, 5000 and 7000 pounds propellant, that evolved from preliminary sizing studies. HEUS configurations were developed for each motor size, and weight statements defined.

A mission model analysis was used to determine the best motor size for the final HEUS configuration. The impact of the increased propellant weight up to 7000 pounds in the HEUS was to allow the use of a smaller booster for a given mission. However, this impact was secondary compared to the fundamental impact of being able to shut down and restart the restartable solid motor.

Based on this analysis, coupled with the fact that the feasibility demonstration motor was in the 3000 pounds size range, the baseline HEUS configuration of approximately 3000 pounds propellant was selected for the final phase of the study.

1.2.3.3 HEUS-RS Launch Program Evaluation

Launch vehicle performance for the HEUS configuration was determined on a general basis. Payload data for East, Polar and 100^{o} inclination orbits with the restartable BE-15B2, TE-M-364-2 and TE-M-364-4 was developed. A general comparison of the relative performance of these configurations is shown in Figure 1.2.3.3-1.

These data include the non-restartable TE-M-364-2 and TE-M-364-4 Burner II stages on a three strap-on Thorad. A significant performance increase can be realized with the restartable stages. The impact of this performance gain is not totally apparent in the mission model evaluation because program performance requirements naturally gravitate to the current launch vehicle capability.

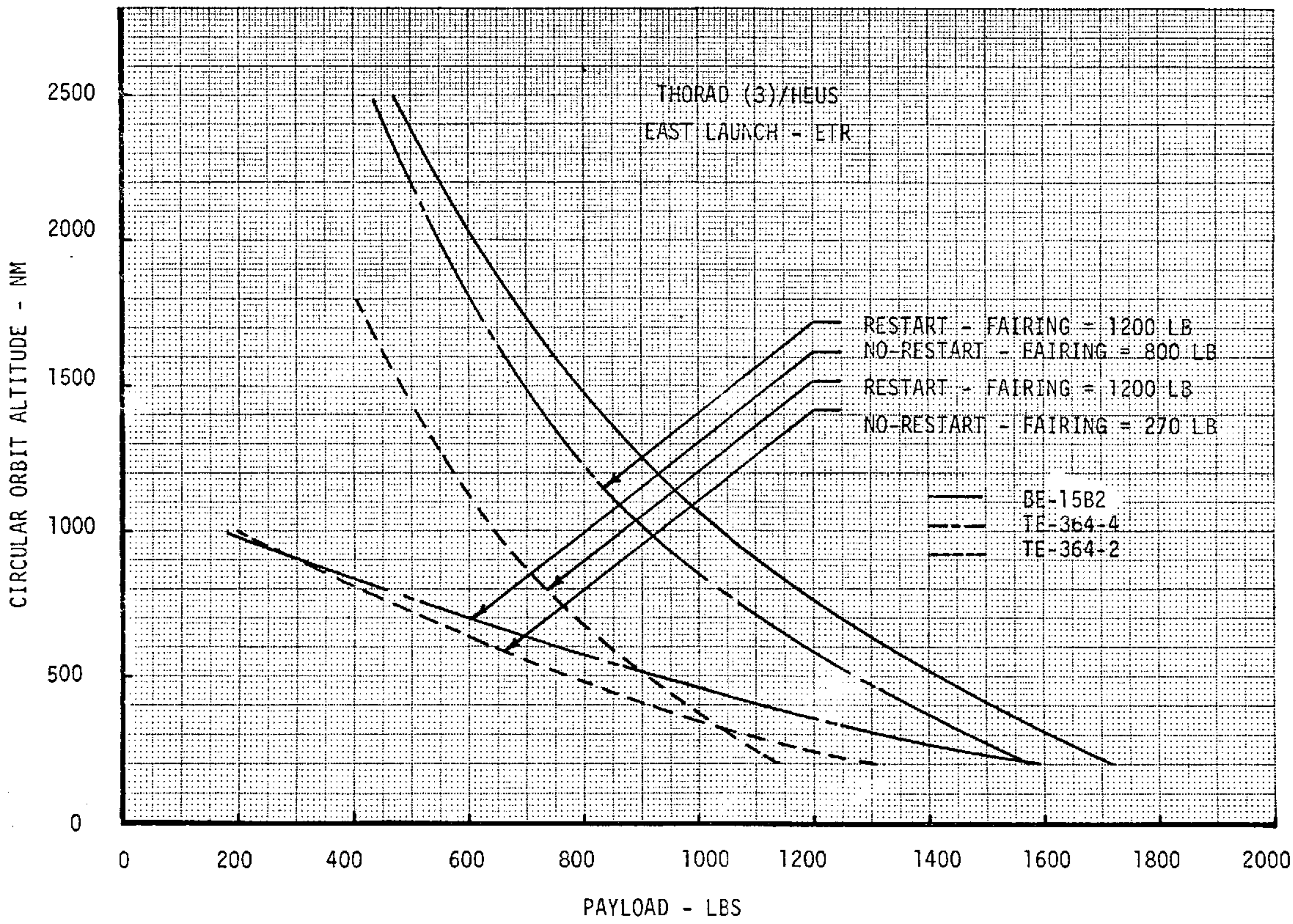


FIGURE 1.2.3.3-1

1.2.3.3 (Cont'd)

The performance regime available with the HEUS would certainly attract mission assignments were it a part of the NASA launch vehicle stable.

1.2.3.4 Task 4 Summary

The costing of the alternate launch vehicle program is contained in Volume 2.

1.2.3.5 Task 5 Summary

The comparison of the costs between Task 3 and Task 4 are contained in Volume 2.

1.2.3.6 HEUS/BII Shuttle Applications

The HEUS configurations provide an attractive capability for Space Shuttle interim tug. General performance data was dev eloped to show the HEUS capability for various orbit attitudes and inclination changes. The HEUS configurations provide almost total coverage for the low earth orbit missions of the study mission model.

1.2.4 Conclusions and Recommendations

The conclusions and recommendations resulting from this study are as follows:

1. HEUS configurations have a significant impact on low earth orbit missions.

2. Advantages of restartable solids are not completely demonstrated by analysis of this particular mission model since the model was based on existing launch capabilities.

3. Incorporation of quench-restart capability in an existing motor of the 2000 to 2500 pound propellant weight class provides nearly the same low earth orbit capability as the 3000 pound propellant HEUS motor and should provide a significant reduction in development cost.

4. HEUS could provide complete coverage of the low earth orbit missions with small changes to mission requirements for shuttle applications.

5. Larger propellant weight configurations or tandem configurations would be required to provide synchronous equatorial capability in the shuttle applications.

6. Additional study is required to determine HEUS compatibility with the shuttle.

2.0 STUDY TASK RESULTS

2.1 LAUNCH PROGRAM DEFINITION

The mission model used for the HEUS study is shown in Table 2-1. These data reflect the mission model provided at the beginning of the study. The study results show the prime area for application of the HEUS configuration are the low earth orbit missions. The synchronous equatorial and escape missions require a Delta or Centaur stage that already have restart capabilities. In these applications the non-restartable motor provides a greater performance capability.

Many of the missions in the mission model did not show a launch vehicle assignment or showed a vehicle that could not meet the mission requirements. In these cases assignments were made from the NASA "Launch Vehicle Estimating Factors for Advanced Planning" 1971 and 1972 editions.

The mission model included many Scout missions that were included in the preliminary sizing studies but were deleted for the final mission analysis.

The actual orbit parameters were used to determine the HEUS assignments. Characteristic velocity requirements were provided but were not consistent. These data are shown on the mission model but were not the criteria for HEUS assignments.

Mission model data for USAF missions was not provided in sufficient detail to allow an overall program comparison.

2.2 UPPER STAGE CONFIGURATION DEFINITION

2.2.1 Task Requirement

Preliminary parametric performance trades for the missions shown in the mission model were to be performed to determine the HEUS configuration requirements. "Rubber" HEUS configurations for each booster and mission class, were to be defined. This task was to determine the sensitivity of the HEUS propellant weight to the mission model.

2.2.2 HEUS - Rubber Configurations

Preliminary weight-estimates were obtained to determine the optimum HEUS configuration as a function of propellant weight and delivered payload. These weights shown in Table 2.2-1 represent "growth" Burner II data used with the restartable motor and large payloads. The fixed weight represents a 3-axis guidance system, telemetry system, power and coast attitude control system. The reaction control system weight has an allowance for H_2O_2 motors, tanks, residuals and pressurization system. The structure weight allowance is based on previous Burner II experience with large payloads. This weight is highly dependent on the booster selected for the mission. The rocket motor weight data was obtained from Hercules Inc.

TABLE 2-1

HEUS - LOW EARTH ORBIT MISSIONS

MISSION	74	75	76	77	78	79	80	81 (→ SHUTTLE MISSIONS)	82	83	84	85	86	87	88	89	90	WEIGHT	CHARACTERISTIC VELOCITY	AP	PER	INCL	LAUNCH VEHICLE
ESSA WORLD WEATHER WATCH			1		1	1												1800	28900	600	600	101°	ATLAS/CENTAUR
ESSA LOW	1																	675	29450	700	700	101°	TAT(3C)/DELTA
ESSA LOW			1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1200	29450	700	700	101°	TAT(9C)/DELTA/ TE 364
ORBITAL SUPPORT MISSIONS									1		1		1		1		1	1000-3000	26500	350	350	28.5°	TAT(9C)/DELTA/ TE 364
ORBITAL SUPPORT MISSIONS										1		1		1		1		3000-5000	26500	350	350	28.5°	ATLAS/CENTAUR
NIMBUS	1																	1670	28850	600	600	100°	TAT(6C)/DELTA
EOS (TYPE I)		1	1	1														2500	29250	500	500	99°	ATLAS/CENTAUR
EOS (TYPE II)					1	1	1											3800	29250	500	500	99°	ATLAS/CENTAUR
EOS (TYPE III)								1	1	1	1	1	1	1	1	1	1	7500	29250	500	500	99°	ATLAS/CENTAUR
EPS A		1																600	27350	160	160	90°	TAT(3C)/DELTA
EPS B			1															600	27500	350	350	90°	TAT(3C)/DELTA
TIROS N		1																1000	29160	700	700	101°	TAT(3C)/DELTA
TIROS O								1				1					1	1500	29160	700	700	101°	ATLAS/CENTAUR
POLAR ERS			1	2	1													2500	29250	500	500	99°	ATLAS/CENTAUR
MULTI-DISCIP EARTH OBSERV.			1		1		1	1		1	1		1	1		1	1	2500	29250	500	500	99°	ATLAS/CENTAUR
SEA - SAT						1												400	28000	400	400	90°	TAT(3C)/DELTA
MAGNETIC SURVEY SAT.										1		1		1		1		600	27200	200	200	90°	TAT(3C)/DELTA
LARGE SOLAR OBSERV.										1								22000	26500	350	350	28.5°	TITAN IIIC
LARGE RADIO OBSERV.												1						22000	26500	250	250	28.5°	TITAN IIIC
LST								1										22000	26400	30C	300	33.0°	TITAN IIIC
LST												1						30000	26400	300	300	33.0°	TITAN$_7$IIIC
HEAO		1	1			1		1										21000	25900	200	200	28.5°	TITAN IIIC
HIGH ENERGY COSMIC LAB															1			30000	26400	350	350	28.5°	TITAN$_7$IIIC
OSO I-M		1	1		1		1			1								2000	26400	300	300	28.5°	TAT(3C)/DELTA
ASTRONOMY EXPLORER "B"				1		1		1		1		1				1		1000	26450	350	350	28.5°	TAT(3C)/DELTA
ATMOSPHERE EXPLORER D	1																	1000	29600	2100	80	90°	TAT(6C)/DELTA
ATMOSPHERE EXPLORER E		1																1000	31300	2100	80	15°	TAT(6C)/DELTA

2

TABLE 2-1

HEUS - LOW EARTH ORBIT MISSIONS (CONTINUED)

MISSION	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	WEIGHT	CHARACTERISTIC VELOCITY	AP	PER	INCL	LAUNCH VEHICLE
								→ SHUTTLE MISSIONS															
LOWER MAGNETOSPHERE -B						1		1		1		1		1		1		1000	28000	900	900	28.5	TAT(6C)/DELTA/ TE364
RELATIVITY B-D										1				1			1	2000	27900	430	430	90^o	TAT(3C)/DELTA/ TE364
GRAVITY/RELATIVITY A,C,E							1				1						1	500	26300	300	300	90^o	TAT(3C)/DELTA
PHYSICS EXPLORER			2	1	2	1	2	1										600	29180	800	800	90^o	TAT(3C)/DELTA
EARTH RESOURCES SURVEY		1		1		1		1		1		1		1		1		2000	27900	300	300	98^o	TAT(9C)/DELTA
OAO -D	1																	4660	26600	400	400	28.5	ATLAS/CENTAUR
OAO E-G				1	1	1												6000	26600	400	400	28.5	ATLAS/CENTAUR
SATS		1			1		1		1		1		1		1		1	600	30700	300	300	90^o	TAT(3C)/DELTA

TABLE 2-1

SYNCH EQ. & HIGH ORBIT

MISSION	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	WEIGHT	CHARACTERISTIC VELOCITY	AP	PER	INCL	LAUNCH VEHICLE
SEOS					1				1		1		1		1		1	1000	33600	19300	100	28.5	TAT(3C)/DELTA
SMS C,D				1		1												1300	33600	19300	100	28.5	TAT(9C)/DELTA /TE364
ATS H			1															2000	33600	19300	100	28.5	ATLAS/CENTAUR
ATS I, J, K				1		1		1		1	1		1		1	1		2000	33600	19300	100	28.5	ATLAS/CENTAUR
SATS			1			1			1			1			1			600	33600	19300	100	28.5	TAT([illegible])/DELTA
MEDICAL NETWORK						2												2000	39600	19300	19300	0.0	TITAN IIID/ CENTAUR
EDUCATION BRDCST SAT							2											2145	39600	19300	19300	0.0	TITAN IIID/ CENTAUR
TROSS						1	2	1										2300	39600	19300	19300	0.0	TITAN IIID/ CENTAUR
COOPERATIVE APPL. SAT									1		1					1		2000	39600	19300	19300	0.0	TITAN IIID/ CENTAUR
SYSTEM TEST SAT				1			2		1	2	1		1	2	1		2	2000	39600	19300	19300	0.0	TITAN IIID/ CENTAUR
IMP KK			1															800	35800	120 K	130	20.6	TAT(9C)/DELTA /TE364
IMP LL						1												675	35700	100 K	200		TAT(6C)/DELTA /TE364
SAS D		1																1200	33600	19300	100	28.5	TAT(6C)/DELTA
RADIO INTERFEROMETRY									1						1			10000	39200	40000	40000		TITAN IIID7/ CENTAUR
KILOMETER WAVE RADIO													1					2000	39200	40000	40000		TITAN IIIC 7
SPECIAL OBSERV. SOLAR ORBIT A											1					1		1000	39600	19300	19300	0.0	ATLAS/CENTAUR
SPECIAL OBSERV. SOLAR ORBIT B											1					1		1000	36200	1.0	A.U.		TAT(9C)/DELTA /TE364 (ST8)
OPTICAL INTERFEROMETRY A												1					1	1500	39600	19300	19300	0.0	ATLAS/CENTAUR
OPTICAL INTERFEROMETRY B												1					1	1600	36200	1.0	A.U.		TITAN IIIB/ CENTAUR

FOLDOUT FRAME

FOLDOUT FRAME

2

TABLE 2-1
PLANETARY & ESCAPE

MISSION	SHUTTLE MISSIONS 74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	WEIGHT	CHARACTERISTIC VELOCITY	AP	PER	INCL	LAUNCH VEHICLE
VIKING 75		2																7500	39400				TITAN IIID/ CENTAUR
VIKING FOLLOW ON						1		1										9700	38400				TITAN IIID7/ CENTAUR
VENUS PLANETARY EXPL./PROBES			1	1	1		1											800	37500				TAT(3C)/DELTA /TE364
JUPITER 'TOPS' ORBITER								1										3180	48300				TITAN IIID/ CENTAUR/BII
GRAND TOUR			1	1		2												1500	51000				TITAN IIID/ CENTAUR/BII
HELIOS	1	1																500	51000				TITAN IIID/ CENTAUR/BII
PIONEER H	1																	560	48000				TITAN IIID/ CENTAUR/TE364
ENCKE							1											2300	46700				TITAN IIID/ CENTAUR/TE364
MARS HIGH DATA RATE ORBITER													1					7000	37800				TITAN IIID/ CENTAUR
VENUS MAPPER										1								7000	38500				TITAN IIID/ CENTAUR
VENUS LANDER														1				6000	38500				TITAN IIID/ CENTAUR
JUPITER PROBE											1							2000	48500				TITAN IIID/ CENTAUR/BII
SATURN ORBITER/PROBES											1							2600	51500				TITAN IIID7/ CENTAUR/BII
HALEY FLYTHROUG												1						1200	38500				TITAN IIID
VENUS EXPLORER ORBITER												1		1				900	38500				TITAN IIID
RELATIVITY									1						1			500	36200	1 A.U.			TAT(3C)/DELTA

FOLDOUT FRAME

FOLDOUT FRAME

TABLE 2.2-1

HEUS - RS

PRELIMINARY WEIGHTS

CONFIGURATION	1	2	3	4	5	6	7	8	9
PAYLOAD	1000	2500	4000	1000	2500	4000	1000	2500	4000
FIXED WEIGHT	73	73	73	73	73	73	73	73	73
STRUCTURE	105	150	195	155	200	245	205	250	295
REACTION CONTROL	65	65	65	89	89	89	113	113	113
MOTOR INERTS	248	248	248	361	361	361	497	497	497
RESERVE H_2O_2	18	18	18	30	30	30	42	42	42
WEIGHT IN ORBIT	1509	3054	4599	1708	3253	4798	1930	3475	5020
VERNIER H_2O_2	18	18	18	30	30	30	42	42	42
MOTOR PROPELLANT	3000	3000	3000	5000	5000	5000	7000	7000	7000
QUENCH	12	12	12	20	20	20	28	28	28
EXPENDED INERTS	15	15	15	25	25	25	35	35	35
CONTROL H_2O_2	8	10	12	13	16	20	18	23	28
IGNITERS	3	3	3	5	5	5	7	7	7
SEPARATION WEIGHT	4565	6112	7659	6801	8349	9898	9060	10610	12160

2.2.2.1 HEUS-RS Motor Sizing

Parametric sizing data for HEUS-RS motors ranging from 3000 to 7000 pounds of propellant was supplied by Hercules Incorporated. This data included the following:

- Motor length and diameter as a function of propellant weight for motor having non-submerged and 35% submerged nozzles (See Figure 2.2.2-1).
- Motor mass fraction and vacuum specific inpulse as a function of propellant weight for motors having non-submerged and 35% submerged nozzles (See Figure 2.2.2-2).
- Water quench system weight as a function of propellant weight (See Figure 2.2.2-3).

A family of motors was generated using the above parametric sizing data and are shown in Figures 2.2.2-4, 2.2.2-5 and 2.2.2-6.

2.2.3 Stage Configuration

The launch vehicle - HEUS stages - payload combinations investigated during this task are shown in Figure 2.2.3-1.

Rubber configurations of upper stages were generated using 3000, 5000, and 7000 pound motors from the parametric data in Paragraph 2.2.2. The upper stages were designed for use on the Standard Thor, 96 inch diameter Thord, Titan IIIB and Titan III/Centaur launch vehicles. These rubber stage configurations are shown in Figures 2.2.3-2 through 2.2.3-13.

Each of the rubber stages was designed using Burner II hexagonal type structure and a three beam attachment to launch vehicle adapters. The largest diameter motors generated from the parametric data were used to keep the stage as short as possible. This provides maximum payload envelope within the fairing and keeps stage weight at a minimum.

All stages were three axis stabilized and included all the flight subsystems required to launch the payloads. The systems were sized to satisfy the requirements of the various HEUS-RS motor and payload combinations.

Basic Burner II reaction control systems were sized to satisfy the control requirements for HEUS motors with propellant weights from 3000 to 7000 pounds and payload weights of 1000, 2500 and 4000 pounds. The Burner II-type reaction control system provides control moments and thrust on command from the guidance system, starting after launch vehicle separation and continuing until payload separation. The system is shown schematically in Figure 2.2.3-14. It is a dual, mono-propellant system using hydrogen peroxide (H_2O_2) and nitrogen (N_2) control motors. Four H_2O_2 motors provide impulse for booster separation, control during solid motor firing, and vernier control (if required) of burnout velocity. Eight 2.2 lb. thrust N_2 motors provide impulse for roll control for all mission phases and attitude control during coast. In addition to the normal control functions during boost, the N_2 system may perform terminal maneuvers for payload positioning followed by optional payload spinup and soft payload separation. The N_2 system capacity

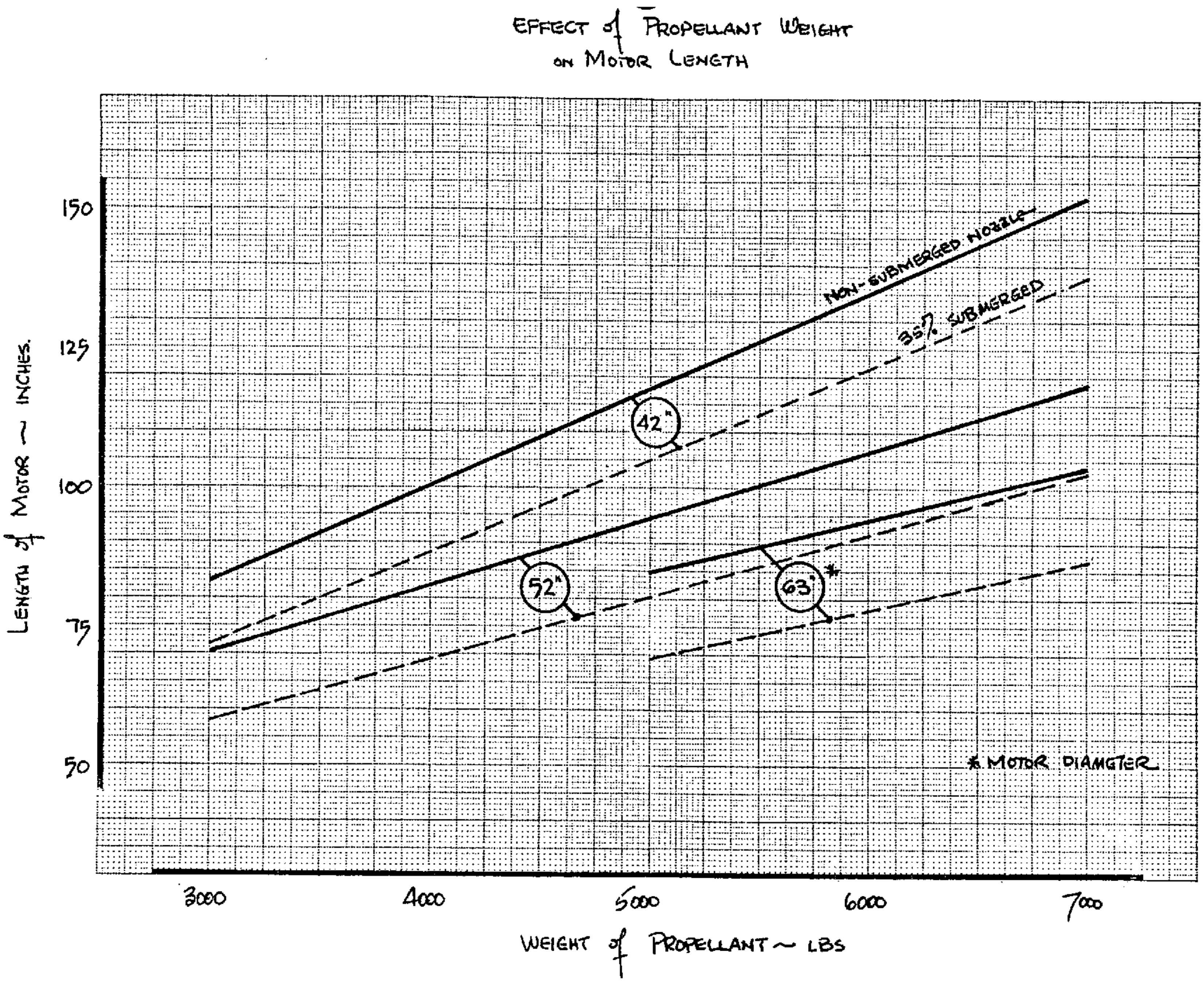

EFFECT of PROPELLANT WEIGHT
on MOTOR LENGTH
LENGTH of MOTOR ~ INCHES.
150
125
100
75
50
NON-SUBMERGED NOZZLE
35% SUBMERGED
42"
52"
63"*
* MOTOR DIAMETER
3000
4000
5000
6000
7000
WEIGHT of PROPELLANT ~ LBS

FIGURE 2.2.2-1

EFFECT of PROPELLANT WEIGHT
ON SPECIFIC IMPULSE & MASS FRACTION

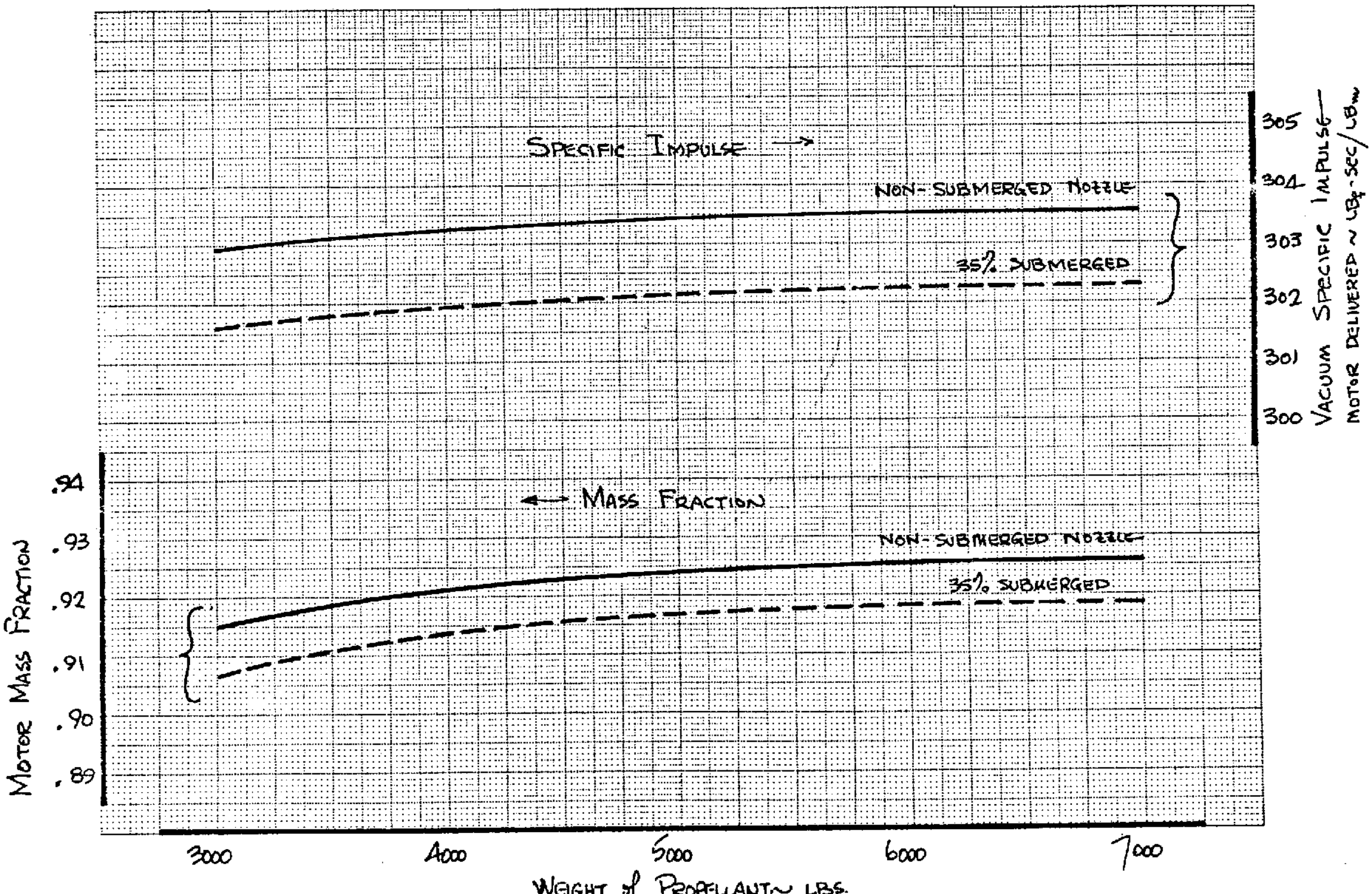


FIGURE 2.2.2-2

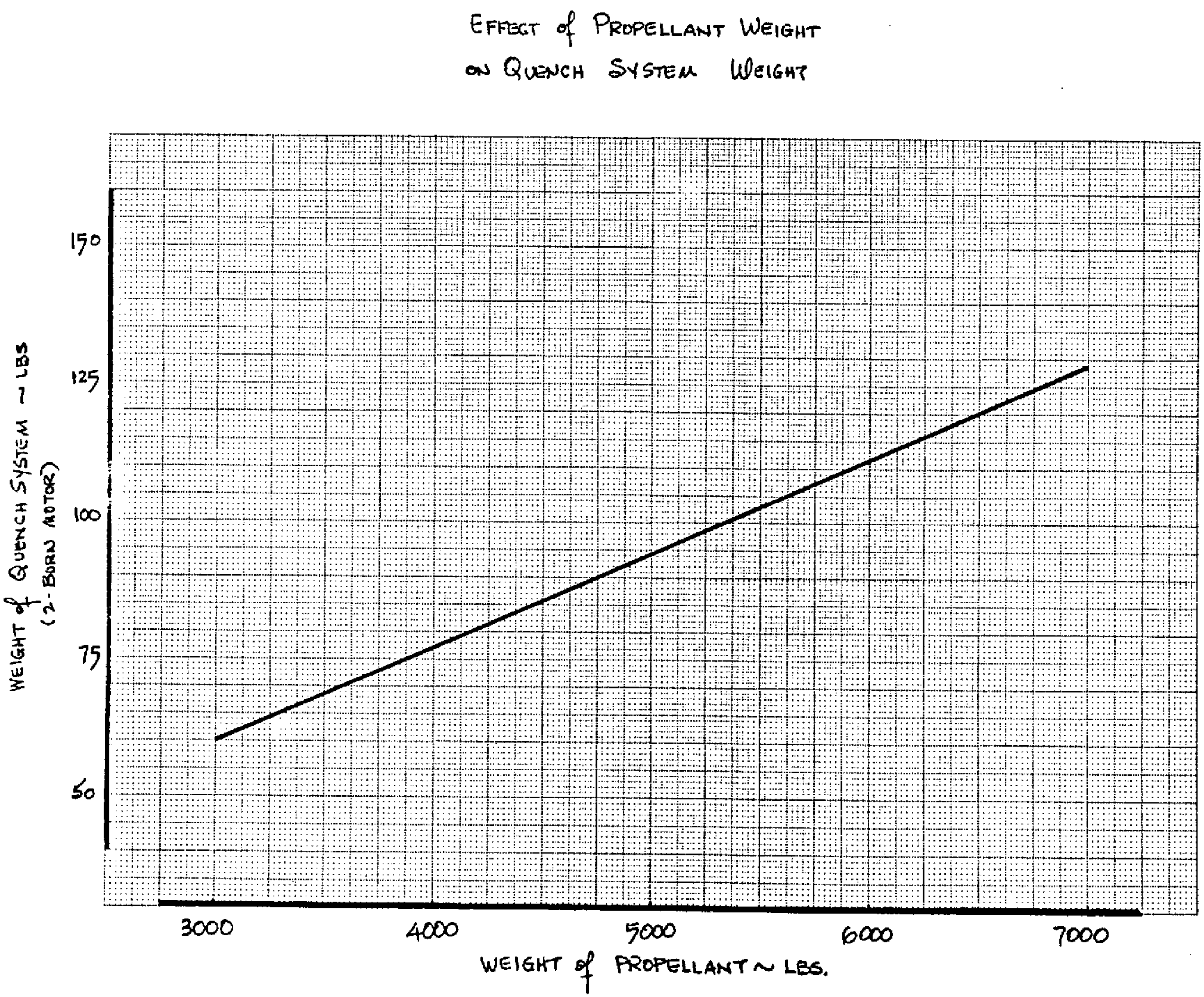

EFFECT of PROPELLANT WEIGHT
ON QUENCH SYSTEM WEIGHT
150
125
100
75
50
WEIGHT of QUENCH SYSTEM ~ LBS
(2-BURN MOTOR)
3000
4000
5000
6000
7000
WEIGHT of PROPELLANT ~ LBS.

FIGURE 2.2.2-3

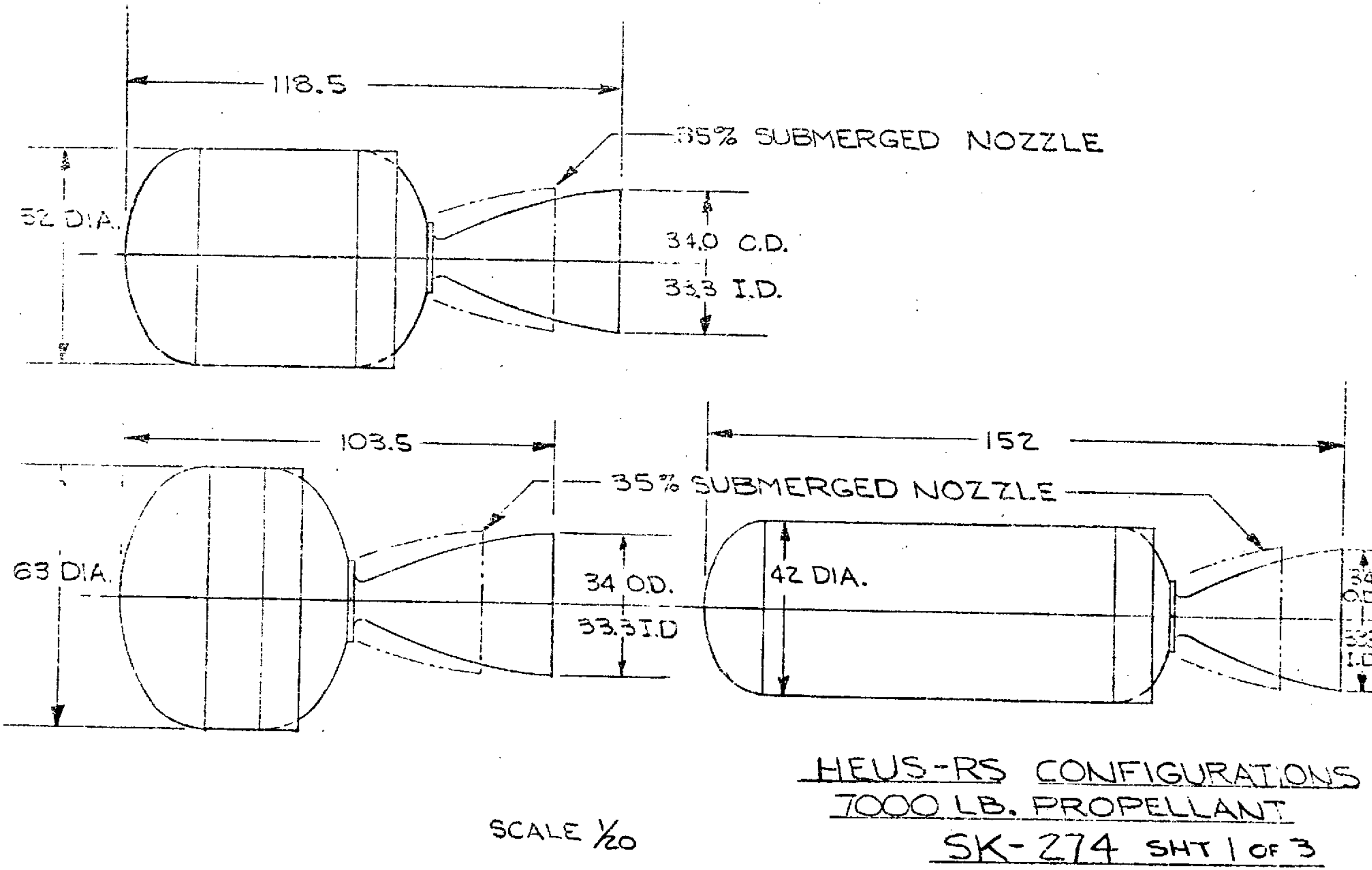

118.5
35% SUBMERGED NOZZLE
52 DIA.
34.0 O.D.
33.3 I.D.
103.5
152
35% SUBMERGED NOZZLE
63 DIA.
34 O.D.
33.3 I.D
42 DIA.
34 O.D
33.3 I.D
HEUS-RS CONFIGURATIONS
7000 LB. PROPELLANT
SK-274 SHT 1 OF 3
SCALE 1/20

FIGURE 2.2.2-4

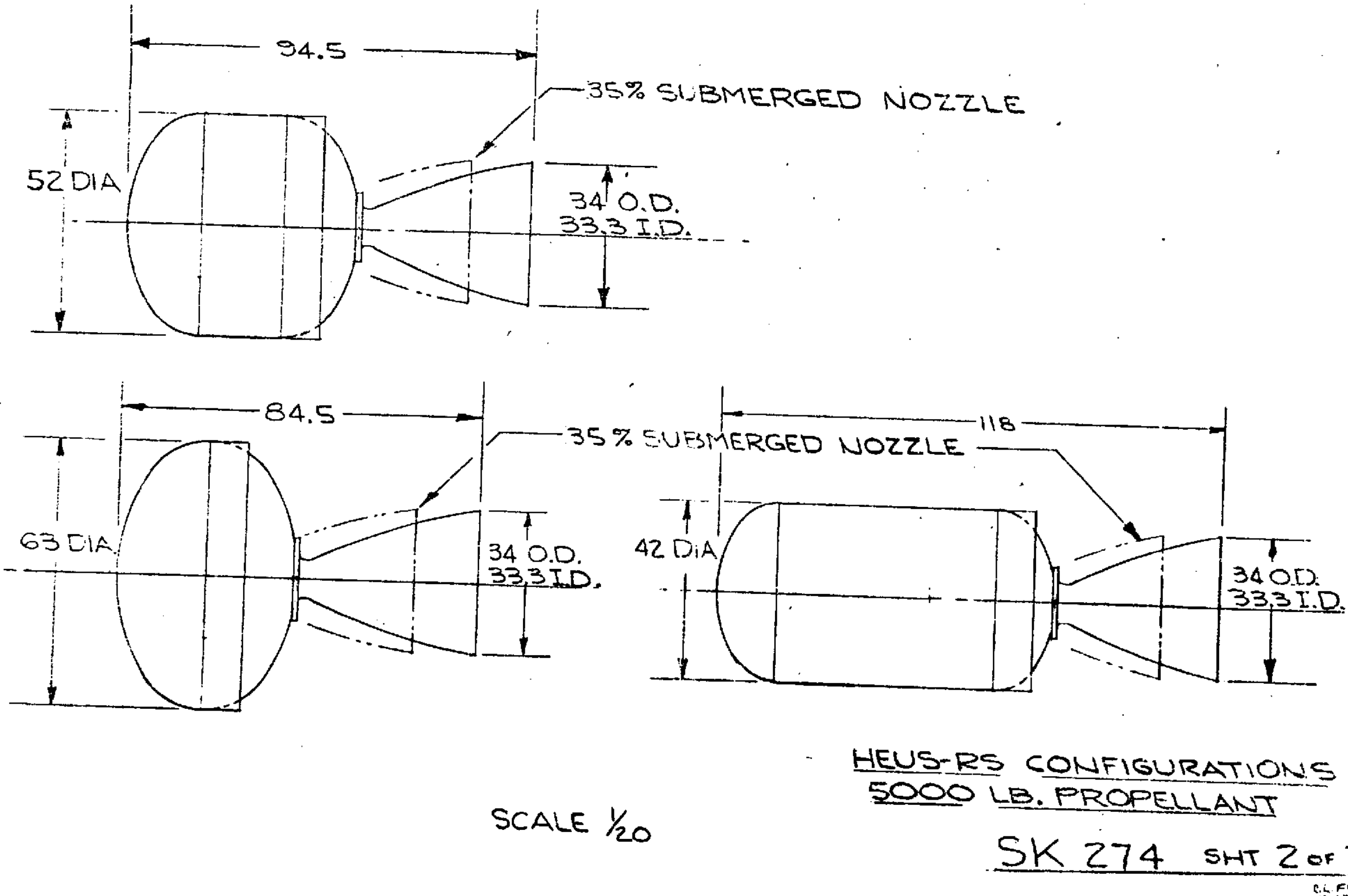
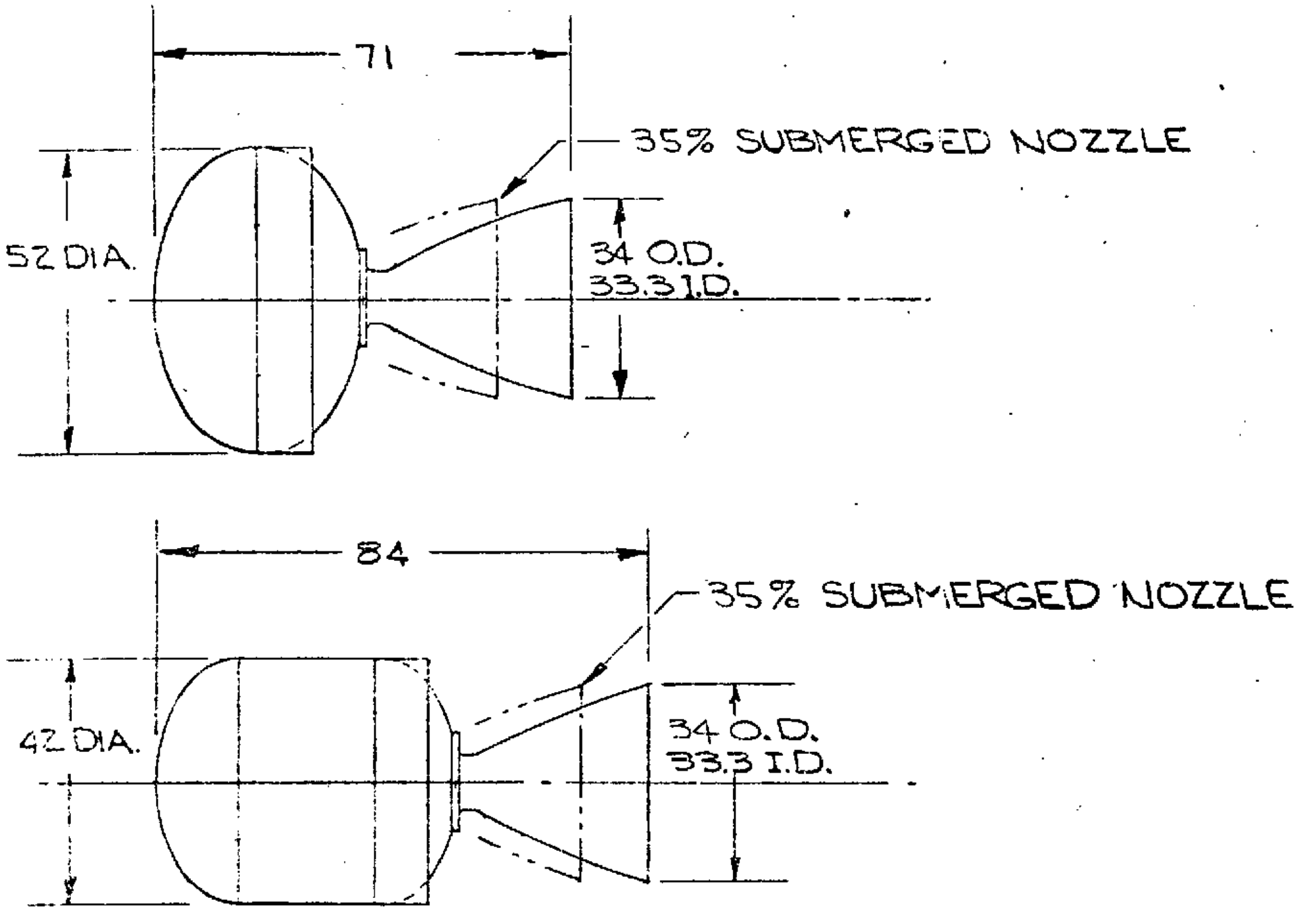

94.5
35% SUBMERGED NOZZLE
52 DIA
34 O.D.
33.3 I.D.
84.5
35% SUBMERGED NOZZLE
63 DIA
34 O.D.
33.3 I.D.
118
42 DIA
34 O.D.
33.3 I.D.
HEUS-RS CONFIGURATIONS
5000 LB. PROPELLANT
SCALE 1/20
SK 274 SHT 2 OF 3

FIGURE 2.2.2-5



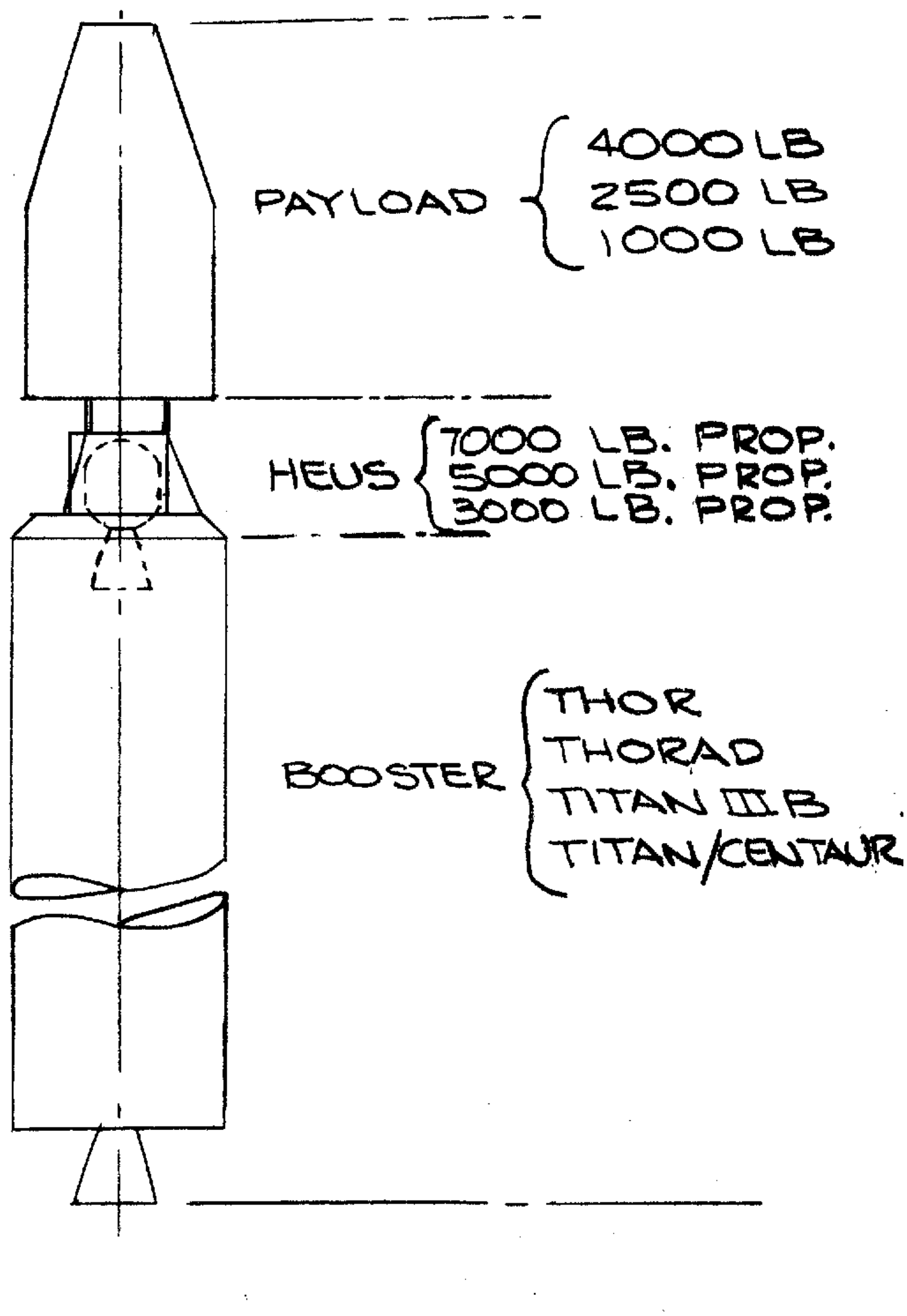
SCALE 1/20

HEUS-RS CONFIGURATIONS

3000 LB. PROPELLANT.

SK 274 SHT 3 OF 3

FIGURE 2.2.2-6



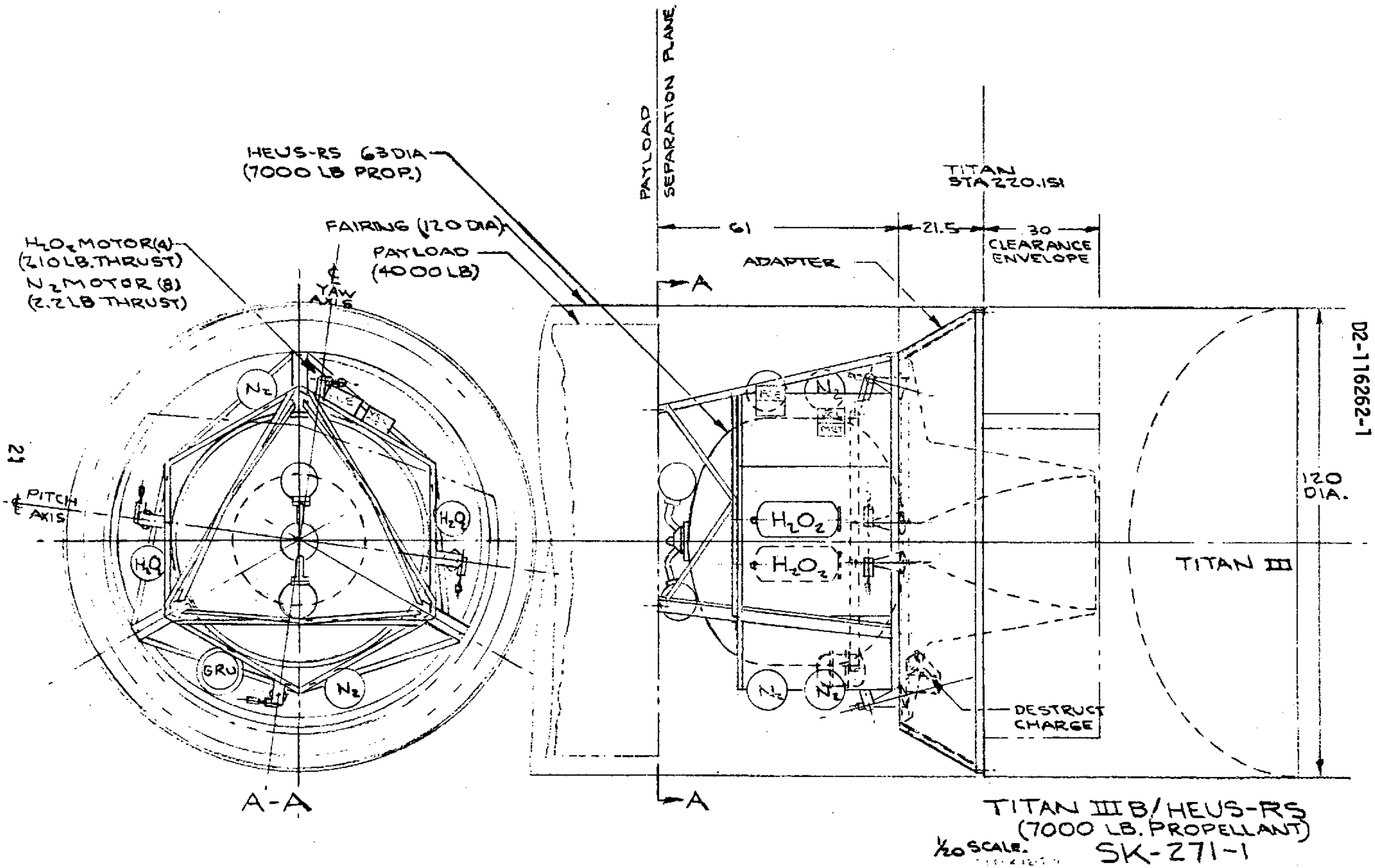
<u>COMBINATIONS</u>

BOOSTER/HEUS = 12

HEUS/PAYLOAD = 9

CONFIGURATION COMBINATIONS

FIGURE 2.2.3-1



HEUS-RS 63 DIA
(7000 LB PROP.)
PAYLOAD SEPARATION PLANE
TITAN STA 220.151
H_2O_2 MOTOR (4)
(210 LB. THRUST)
N_2 MOTOR (8)
(2.2 LB THRUST)
FAIRING (120 DIA)
PAYLOAD
(4000 LB)
61
21.5
30
CLEARANCE ENVELOPE
ADAPTER
YAW AXIS
PITCH AXIS
A
N_2
H_2O_2
GRU
120 DIA.
TITAN III
DESTRUCT CHARGE
A-A
TITAN IIIB/HEUS-RS
(7000 LB. PROPELLANT)
1/20 SCALE.
SK-271-1
D2-116262-1

FIGURE 2.2.2-2

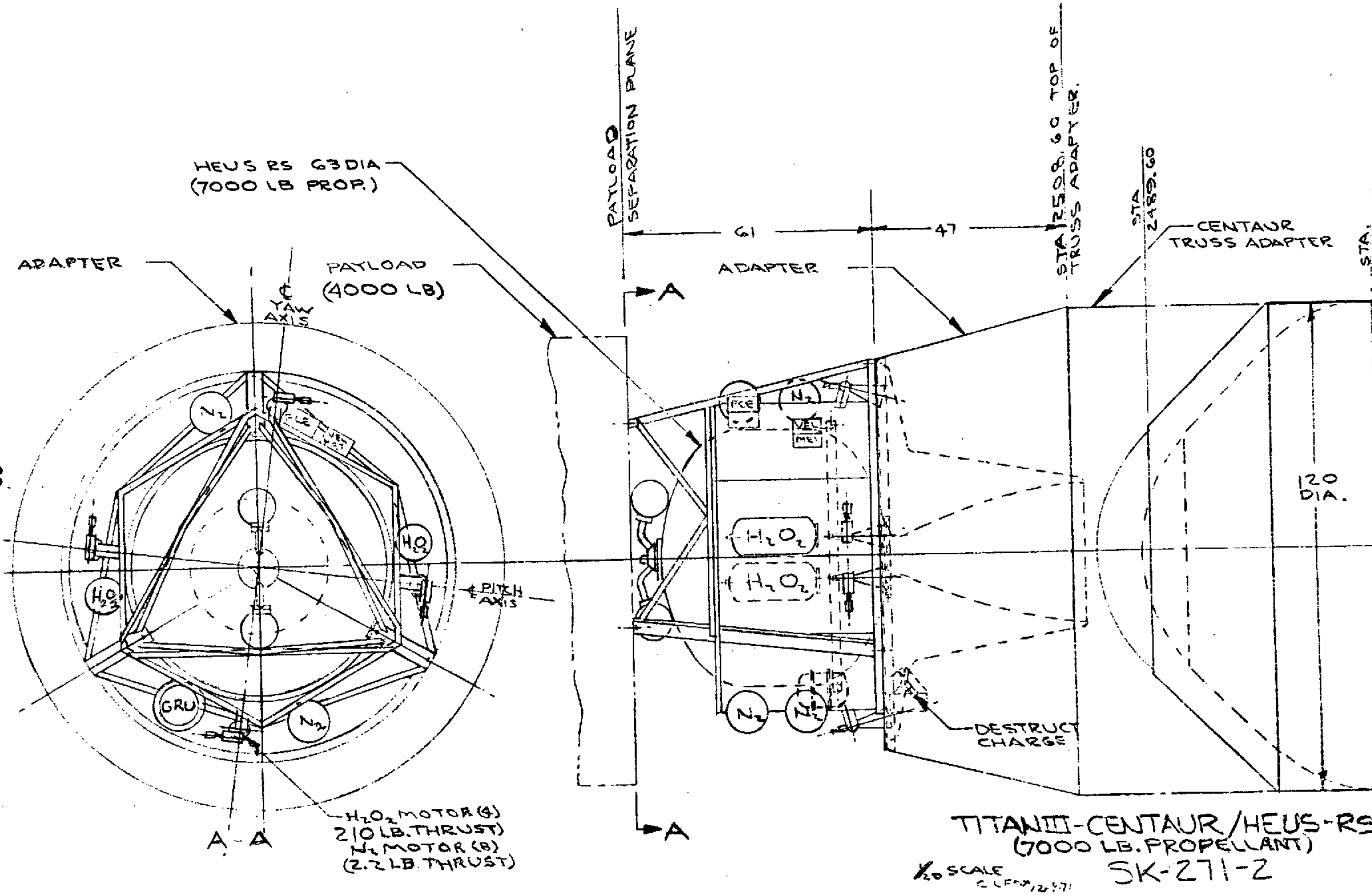
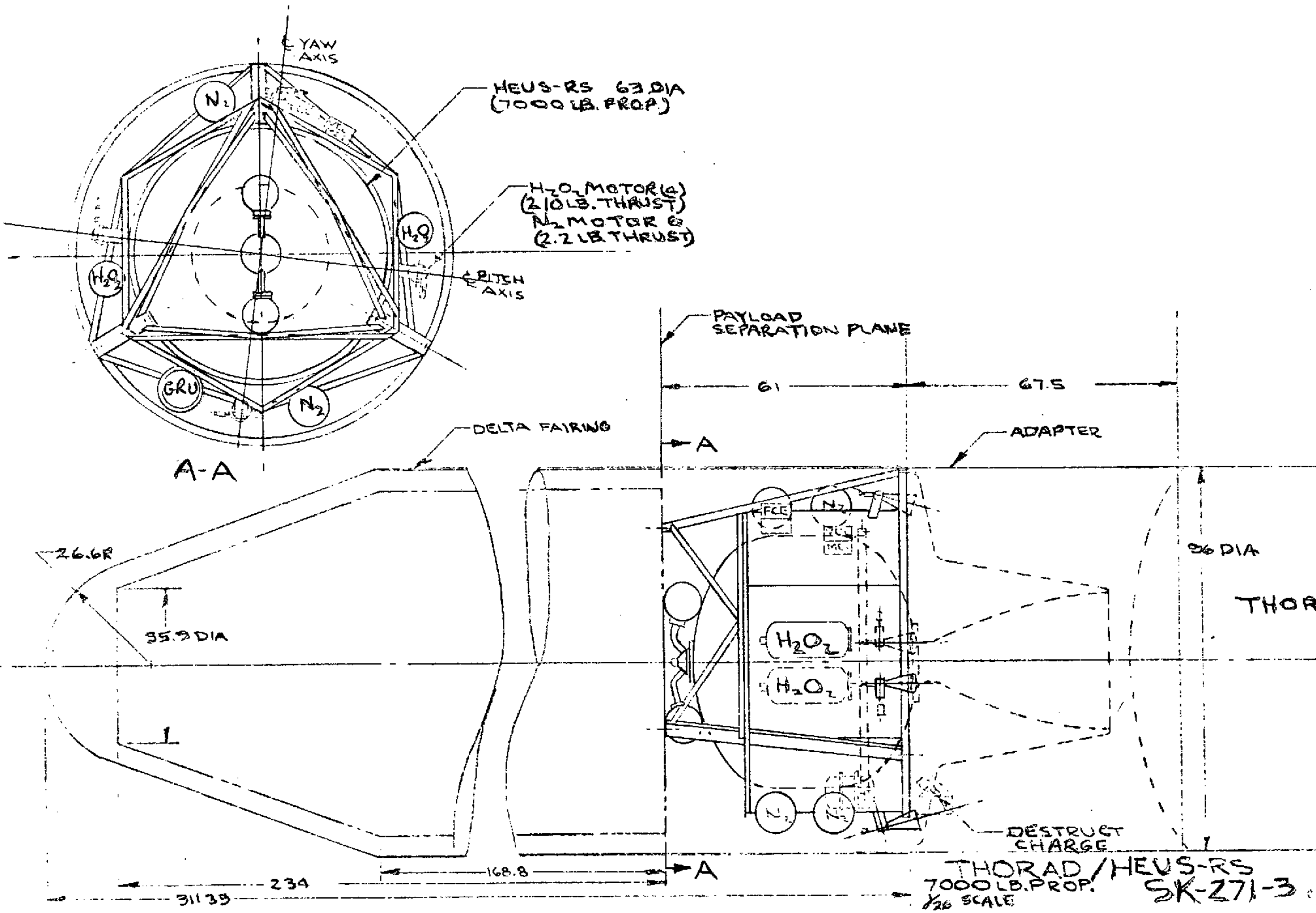
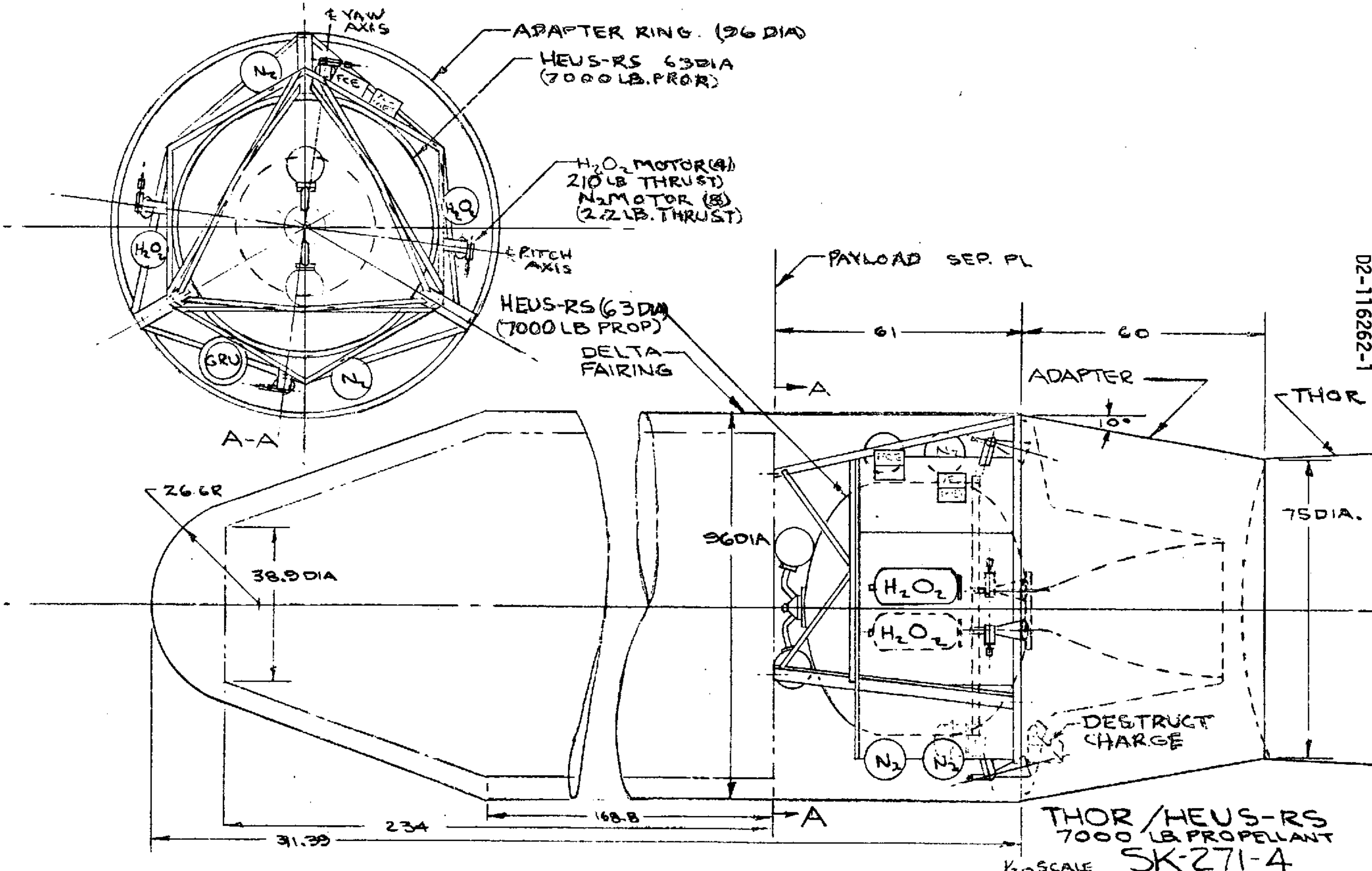

HEUS RS 63 DIA
(7000 LB PROP.)
ADAPTER
PAYLOAD
(4000 LB)
℄ YAW AXIS
PAYLOAD ℄ SEPARATION PLANE
STA 2508.60 TOP OF TRUSS ADAPTER
STA 2489.60
STA 2434.60
61
47
CENTAUR TRUSS ADAPTER
ADAPTER
A
A
N_2
H_2O_2
GRU
℄ PITCH AXIS
FCE
VEL MET
120 DIA.
DESTRUCT CHARGE
H_2O_2 MOTOR (4)
210 LB. THRUST)
N_2 MOTOR (8)
(2.2 LB. THRUST)
A-A
TITAN III-CENTAUR/HEUS-RS
(7000 LB. PROPELLANT)
1/20 SCALE
SK-271-2

FIGURE 2.2.3-3



℄ YAW AXIS
HEUS-RS 63 DIA (7000 LB. PROP.)
H_2O_2 MOTOR (4) (210 LB. THRUST)
N_2 MOTOR 6 (2.2 LB THRUST)
℄ PITCH AXIS
N_2
H_2O_2
GRU
A-A
PAYLOAD SEPARATION PLANE
61
67.5
DELTA FAIRING
ADAPTER
A
26.6R
35.9 DIA
96 DIA
THOR
FCE
N_2
H_2O_2
DESTRUCT CHARGE
168.8
234
311.33
A
THORAD/HEUS-RS
7000 LB. PROP.
1/20 SCALE
SK-271-3

FIGURE 2.2.3-4



℄ YAW AXIS
ADAPTER RING (96 DIA)
HEUS-RS 63 DIA
(7000 LB. PROP.)
H_2O_2 MOTOR (4)
210 LB THRUST)
N_2 MOTOR (8)
(2.2 LB. THRUST)
℄ PITCH AXIS
N_2
H_2O_2
GRU
A-A
HEUS-RS (63 DIA)
(7000 LB PROP)
DELTA FAIRING
PAYLOAD SEP. PL
61
60
A
A
ADAPTER
10°
THOR
75 DIA.
26.6 R
38.5 DIA
96 DIA
DESTRUCT CHARGE
234
168.8
311.39
THOR / HEUS-RS
7000 LB PROPELLANT
1/20 SCALE
SK-271-4

FIGURE 2.2.3-5

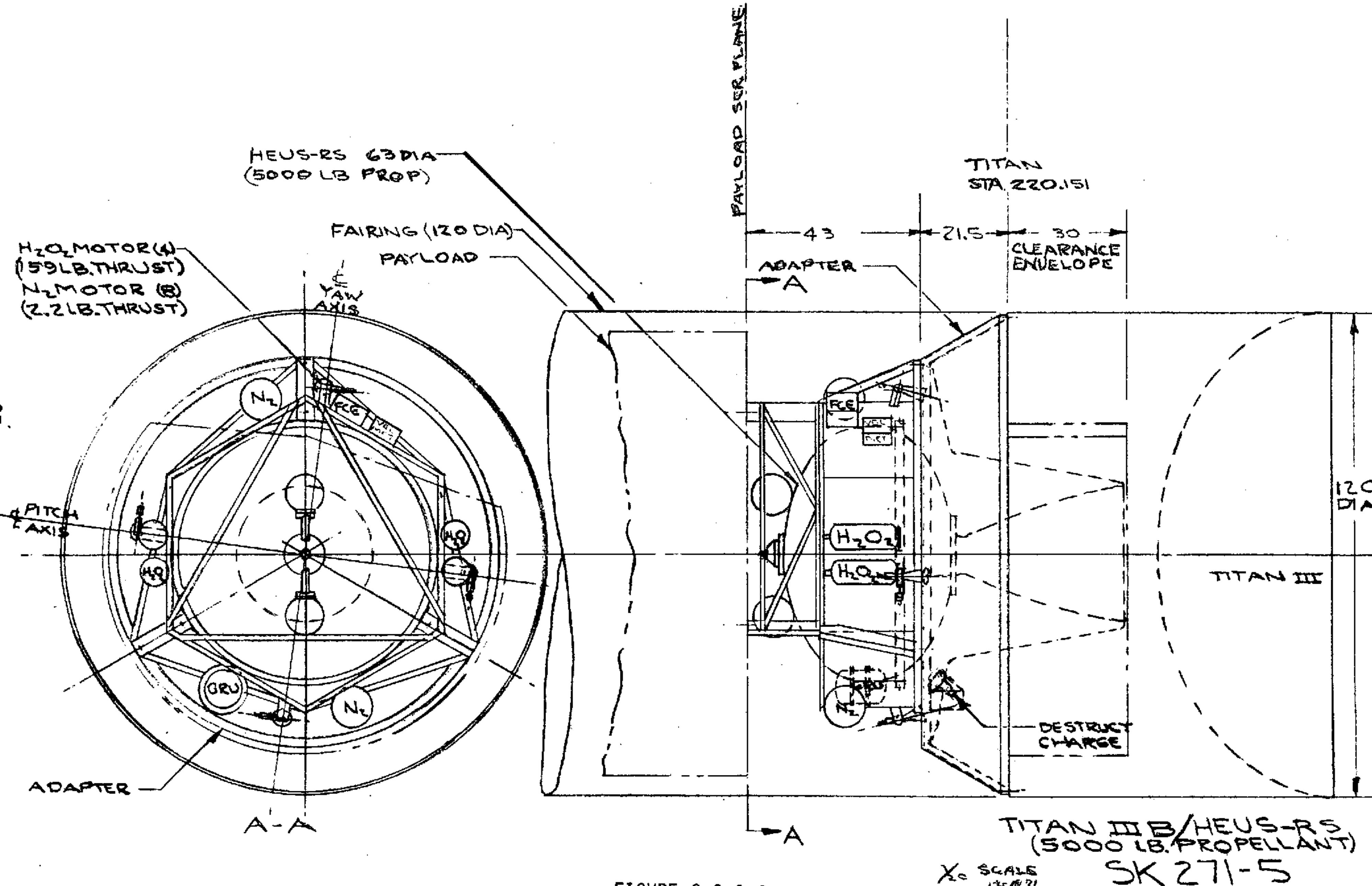
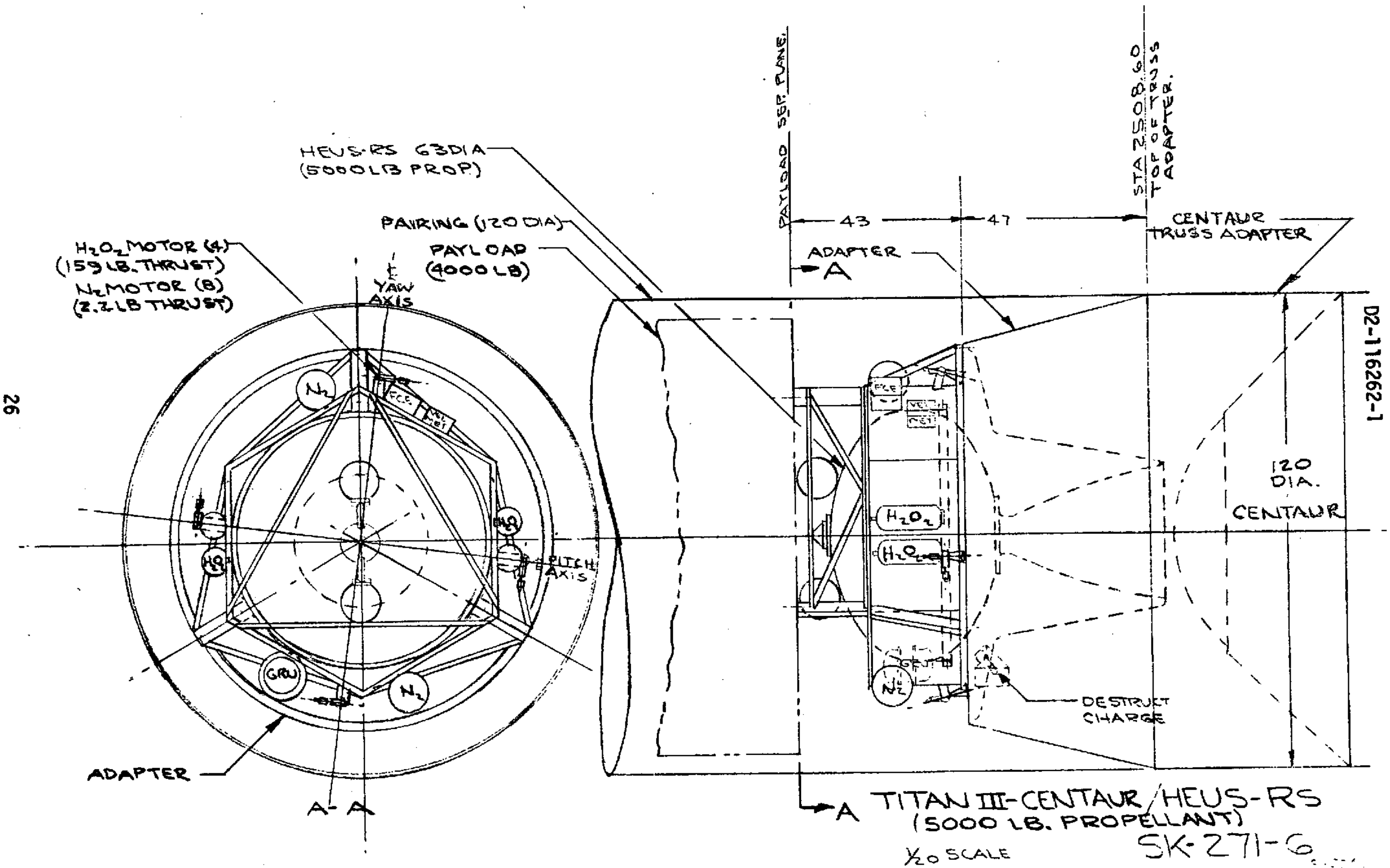

HEUS-RS 63 DIA
(5000 LB PROP)
PAYLOAD SEP. PLANE
TITAN
STA. 220.151
H2O2 MOTOR (4)
(59 LB. THRUST)
N2 MOTOR (8)
(2.2 LB. THRUST)
FAIRING (120 DIA)
PAYLOAD
43
21.5
30
CLEARANCE
ENVELOPE
ADAPTER
A
YAW
AXIS
PITCH
AXIS
N2
FCE
GRU
H2O2
120
DIA.
TITAN III
DESTRUCT
CHARGE
ADAPTER
A-A
A
TITAN III B/HEUS-RS
(5000 LB. PROPELLANT)
SCALE
SK 271-5

FIGURE 2.2.3-6



HEUS-RS 63 DIA
(5000 LB PROP)
FAIRING (120 DIA)
PAYLOAD
(4000 LB)
H_2O_2 MOTOR (4)
(159 LB. THRUST)
N_2 MOTOR (8)
(2.2 LB THRUST)
YAW AXIS
PITCH AXIS
F.C.S.
N_2
H_2O_2
GRU
ADAPTER
A-A
PAYLOAD SEP. PLANE
STA 2508.60 TOP OF TRUSS ADAPTER.
43
47
CENTAUR TRUSS ADAPTER
ADAPTER
A
120 DIA.
CENTAUR
DESTRUCT CHARGE
A
TITAN III-CENTAUR/HEUS-RS
(5000 LB. PROPELLANT)
1/20 SCALE
SK-271-6

FIGURE 2.2.3-7

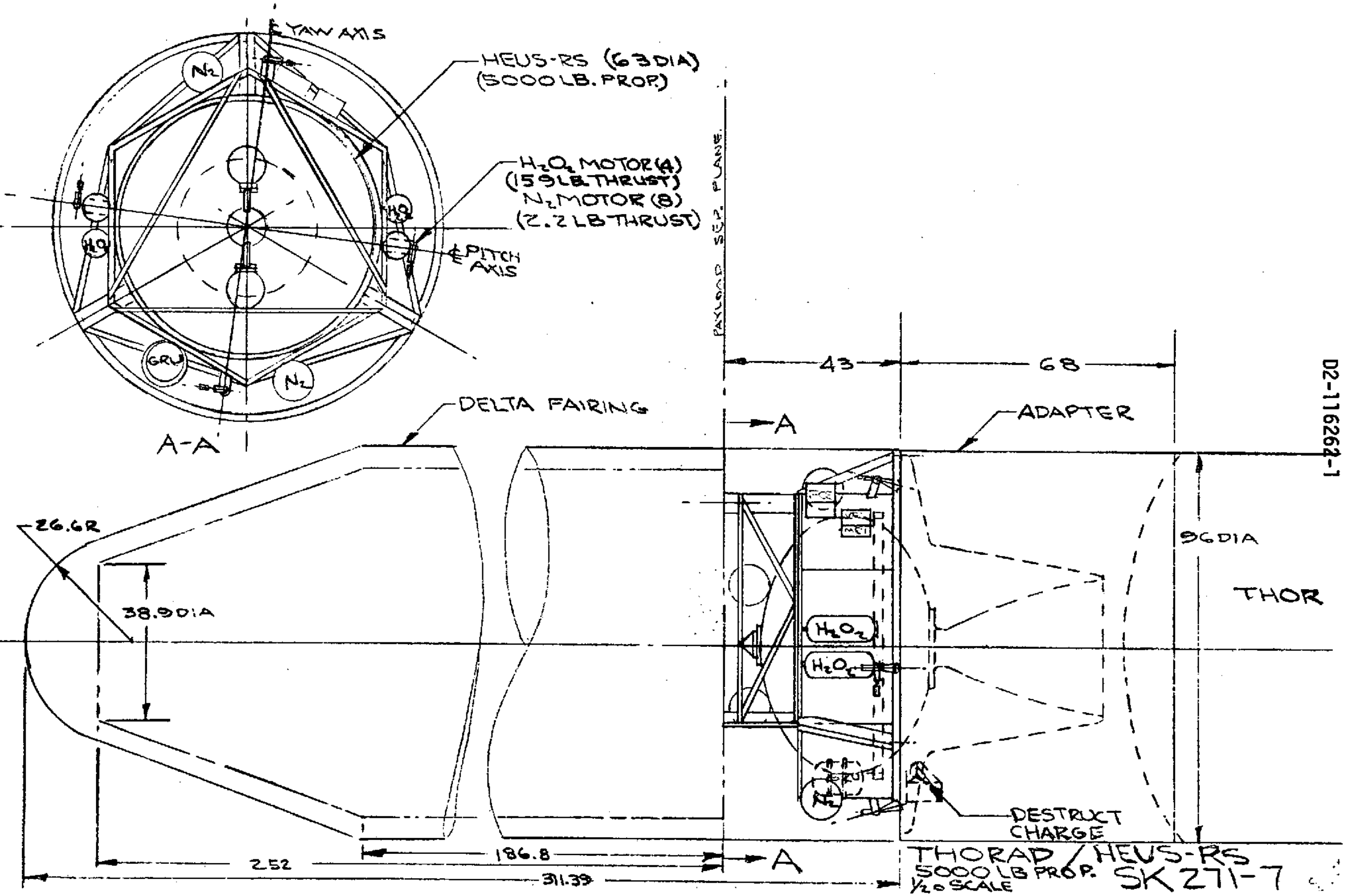

YAW AXIS
HEUS-RS (63 DIA)
(5000 LB. PROP.)
H_2O_2 MOTOR (4)
(15 LB. THRUST)
N_2 MOTOR (8)
(2.2 LB THRUST)
PITCH AXIS
N_2
H_2O_2
GRU
A-A
PAYLOAD SEP. PLANE
43
68
DELTA FAIRING
ADAPTER
A
26.6R
38.9 DIA
96 DIA
THOR
H_2O_2
DESTRUCT CHARGE
252
186.8
311.39
THORAD / HEUS-RS
5000 LB PROP.
1/20 SCALE
SK 271-7

FIGURE 2.2.3-8

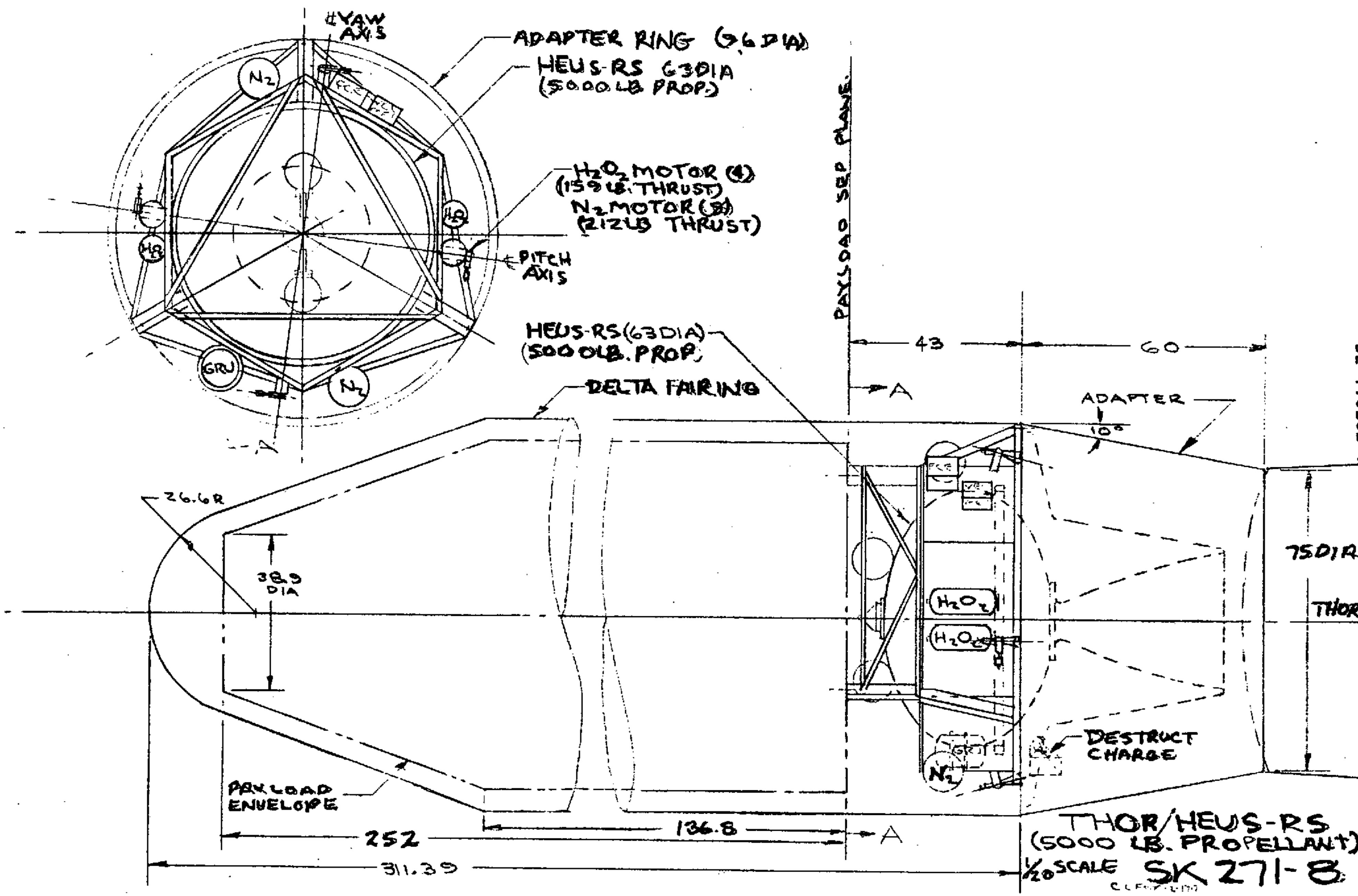

YAW AXIS
ADAPTER RING (76 DIA)
HEUS-RS 63DIA (5000 LB PROP)
N2
FCS
H2O2 MOTOR (4) (159 LB. THRUST)
N2 MOTOR (8) (21 LB THRUST)
PITCH AXIS
GRU
A
PAYLOAD SEP PLANE
43
60
HEUS-RS (63 DIA) (5000 LB. PROP)
DELTA FAIRING
ADAPTER
10°
26.6R
38.9 DIA
75 DIA
THOR
H2O2
DESTRUCT CHARGE
PAYLOAD ENVELOPE
252
136.8
311.39
THOR/HEUS-RS (5000 LB. PROPELLANT)
1/20 SCALE
SK 271-8

FIGURE 2.2.3-9

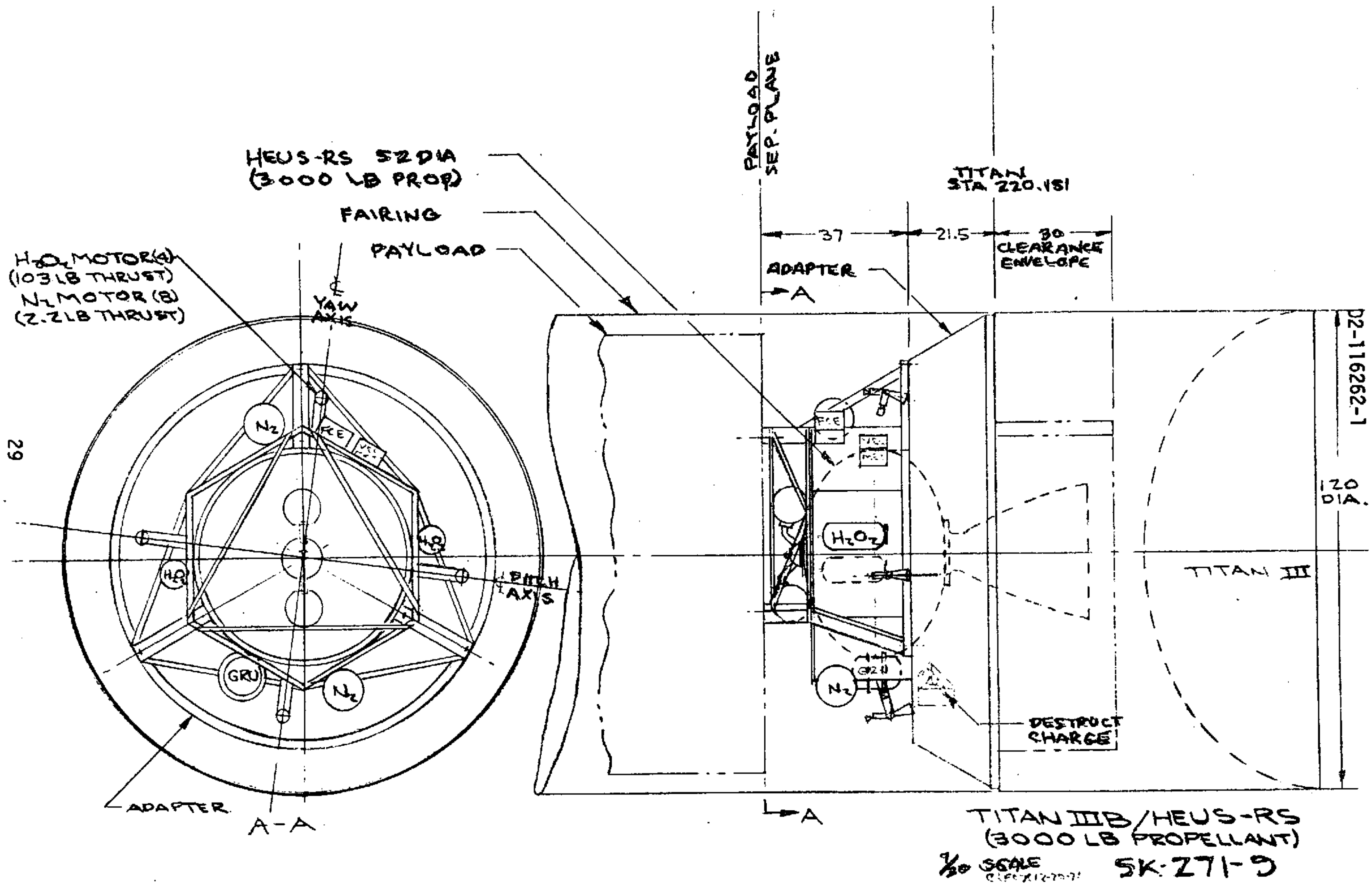


FIGURE 2.2.3-10

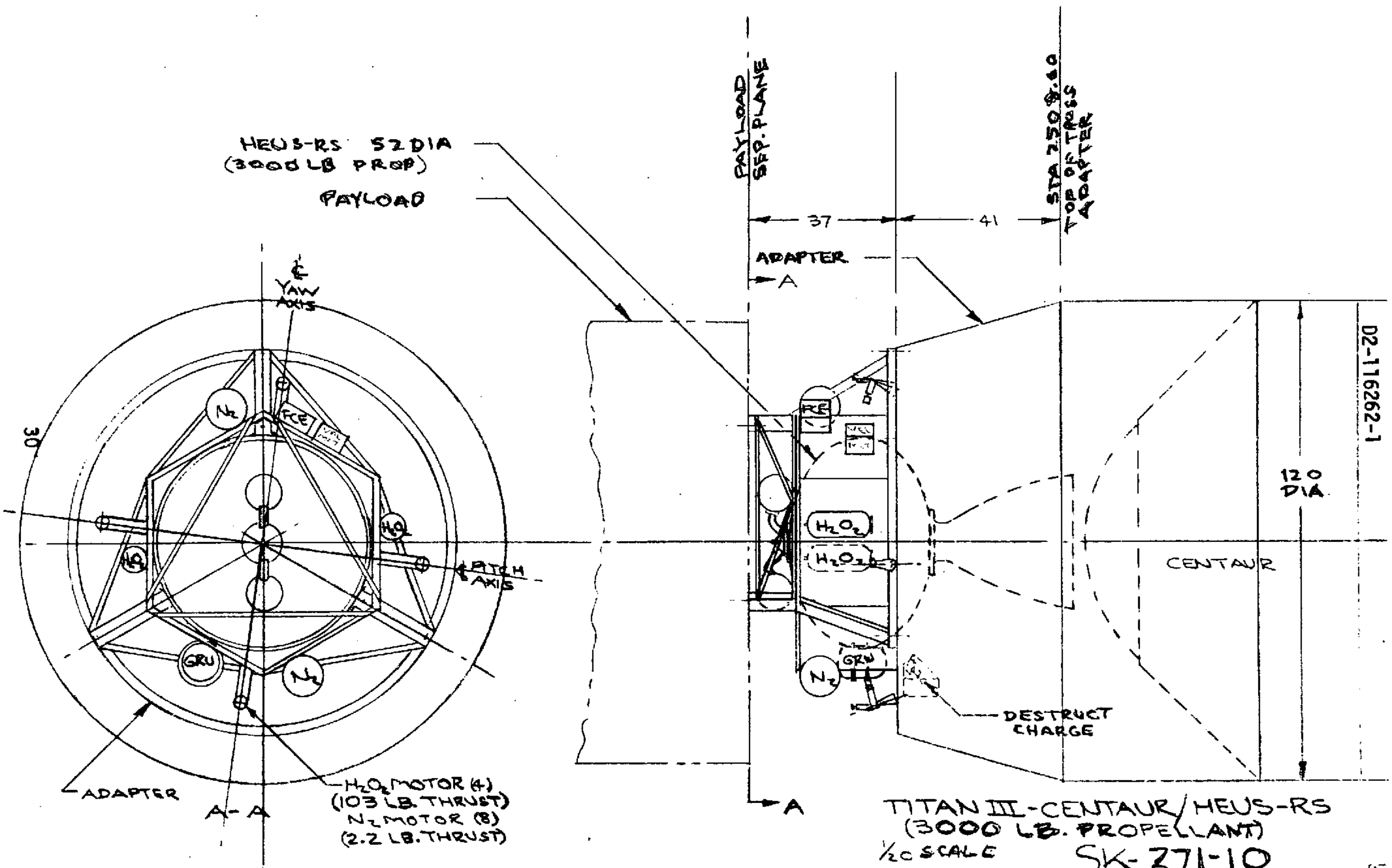


FIGURE 2.2.3-11

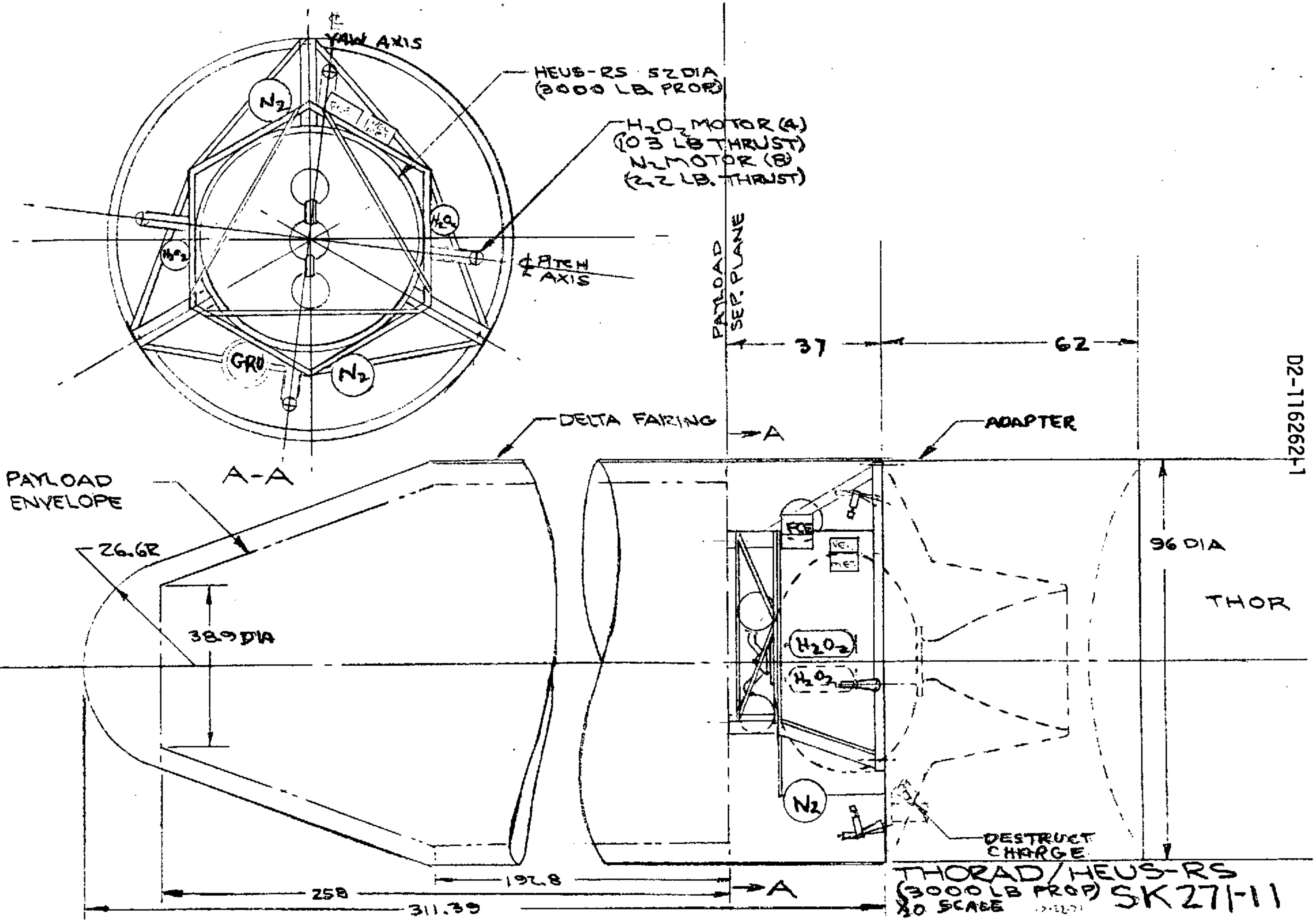


FIGURE 2.2.3-12

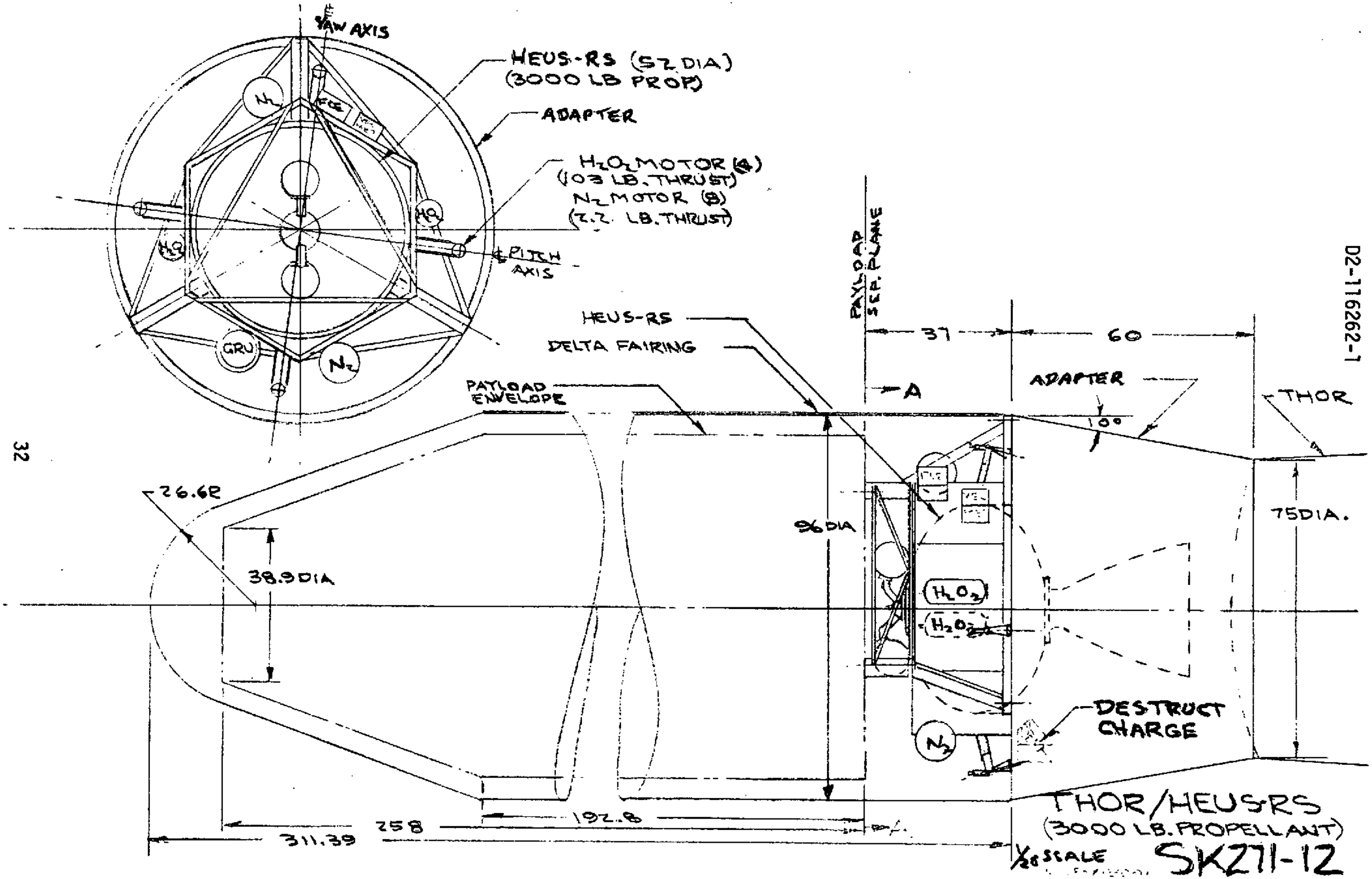


FIGURE 2.2.3-13

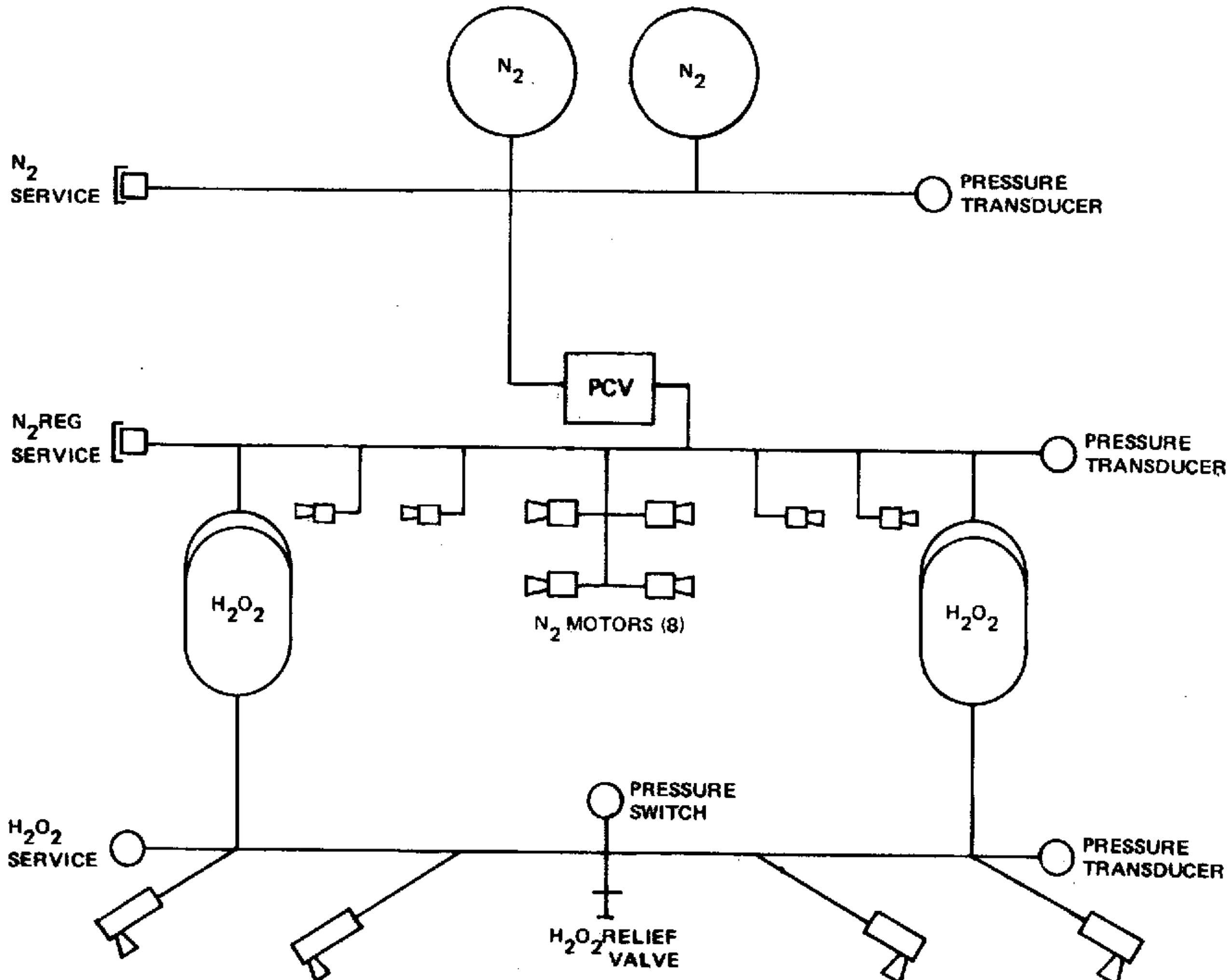


FIGURE 2.2.3-14: RCS SCHEMATIC

2.2.3 (Cont'd)

is sufficient to provide for H_2O_2 system pressurization. The pressure control valve (PCV) regulates the N_2 gas to the required operating pressure for the eight N_2 motors and the H_2O_2 tanks. A relief valve protects the H_2O_2 system against over-pressurization.

The Burner II RCS was sized to accommodate HEUS motors from 3000 to 7000 pound propellant weight and payload weights of 1000, 2500 and 4000 pounds. H_2O_2 motor thrust levels had to be increased, and additional H_2O_2 propellant is required. The N_2 system remains unchanged except for additional N_2 to maintain H_2O_2 system pressurization. H_2O_2 motor thrust is determined by the effective motor moment arm, payload center-of-gravity offset, solid motor thrust mis-alignment and thrust magnitude. The HEUS solid motor action time was held constant at 50 seconds, and motor thrust was increased as propellant weight increased. A non-dimensionalized HEUS motor thrust-time curve is shown in Figure 2.2.3-15. The resultant H_2O_2 control motor dimension less thrust schedule is shown on the lower half of the same figure. H_2O_2 motor thrust, as a function of HEUS motor size and payload weight, required to provide a 1.25 control margin, is shown on Figure 2.2.3-16. The weight of H_2O_2 propellant required for control during HEUS motor firing, plus an allowance for a 6 second launch vehicle separation burn, is shown on the lower half of Figure 2.2.3-16. For comparison, Burner II is loaded with 18.2 pounds of H_2O_2, while the 7000 pound HEUS motor/4000 pound payload combination will require a minimum of 93 pounds of H_2O_2. Tank size, in cubic inches as a function of motor size and payload weight, is shown in Figure 2.2.3-17. Again, Burner II uses two 200-cubic inch tanks while the 7000 pound/4000 pound HEUS concept will require a minimum total capacity of 2000 cubic inches. The data shown in Figures 2.2.3-15,16, and 17 is summarized in Table 2.2.3-1.

2.2.4 Performance Evaluation

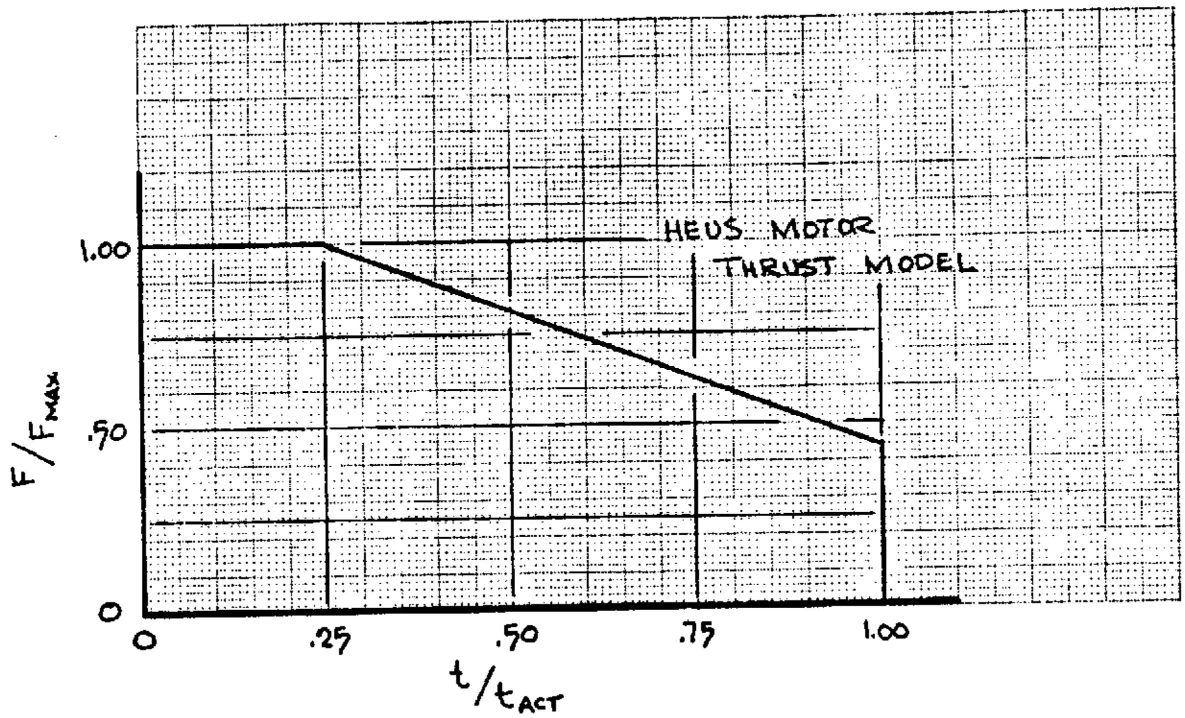
The payload capability was determined for each of the "Rubber" HEUS configurations combined with the selected booster family. Boosters considered were the standard and "straight 8" Thorad with 3, 6, and 9 strap-on casters, the Titan IIIB and the Titan IIID.

Figures 2.2.4-1 through 2.2.4-3 show the payload capability of the standard Thorad with the three rubber HEUS configurations. Similarly, Figures 2.2.4-4 through 2.2.4-6 show the "straight 8" Thorad family. Data provided includes last launch from CTR and polar orbits from WTR. Figures 2.2.4-7 and 2.2.4-8 show the Titan IIIB and Titan IIID parametric performance. These data were used as a basis for evaluation of the mission model to gain an insight into the best HEUS propellant loading.

Each of these figures indicate that the maximum performance would be achieved with a propellant loading greater than 7000 pounds. However, application of these data to the mission model indicates that the 3000 pound propellant motor can provide a significant impact.

Table 2.2.4-1 shows a summary of the potential HEUS use for the 3000, 5000 and 7000 pound propellant weight configurations with respect to the current launch vehicle assignments. These data include Scout missions that were eliminated from consideration in the final phase of the study. The Table shows that the HEUS could meet the mission objectives for 161 out of the 167 launches in the mission model.

THRUST ~ TIME MODELS
HEUS MOTOR & RCS



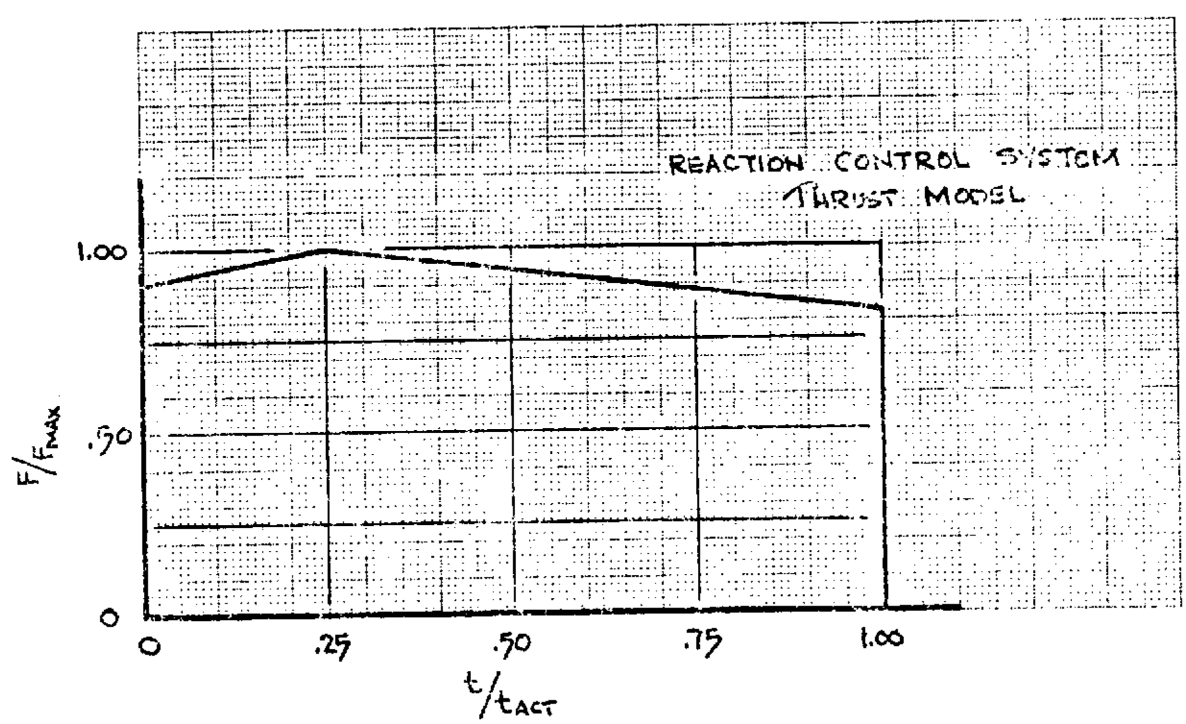
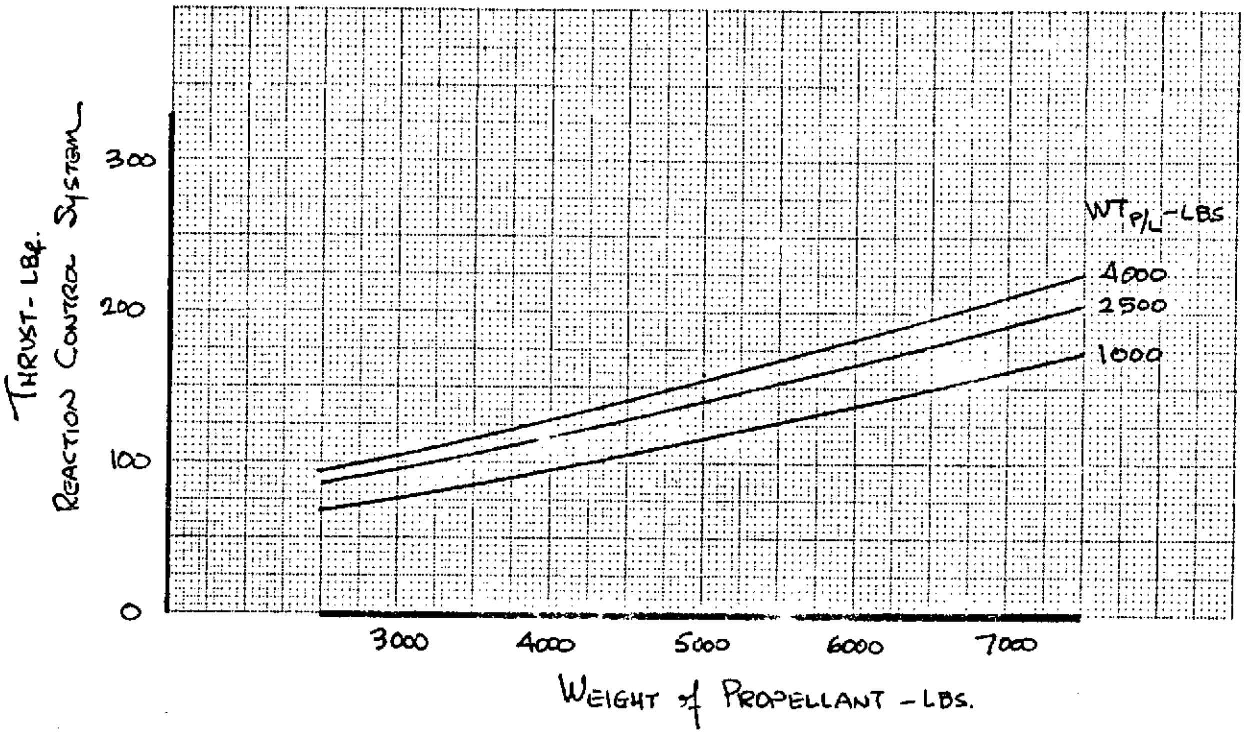


FIGURE 2.2.3-15

REACTION CONTROL SYSTEM
THRUST & H_2O_2 CONTROL WEIGHT



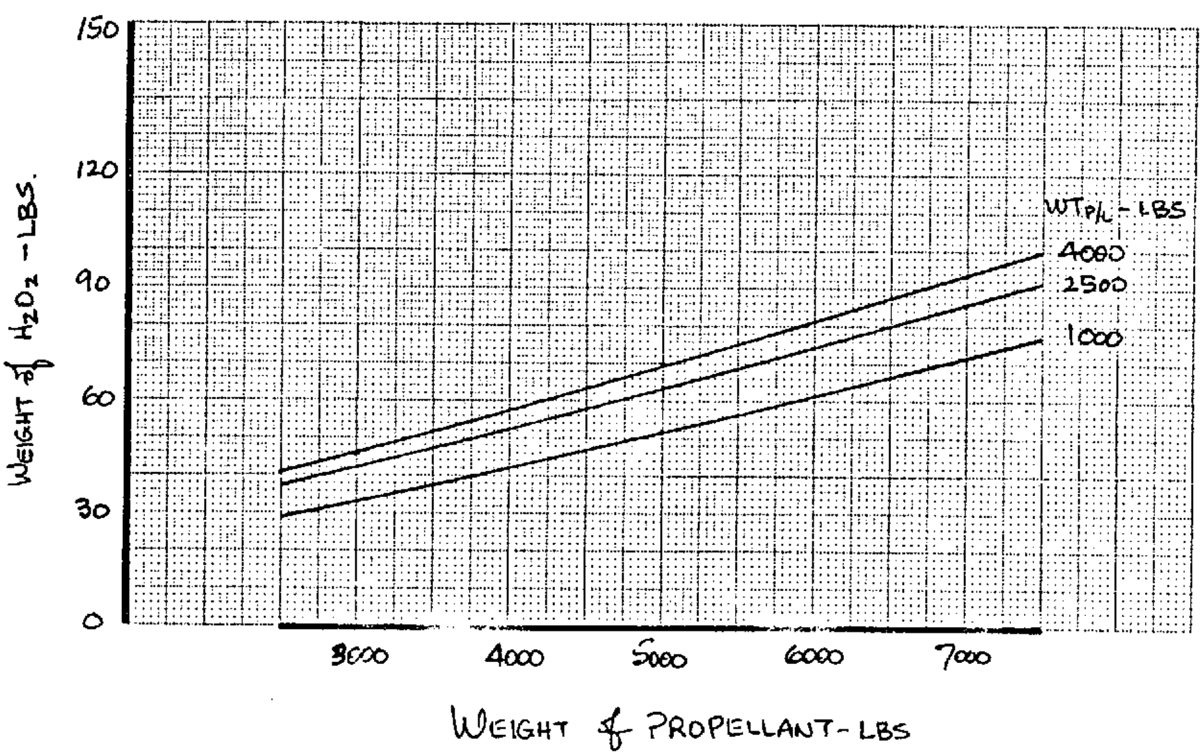


FIGURE 2.2.3-16

H_2O_2 TANKAGE REQUIREMENTS

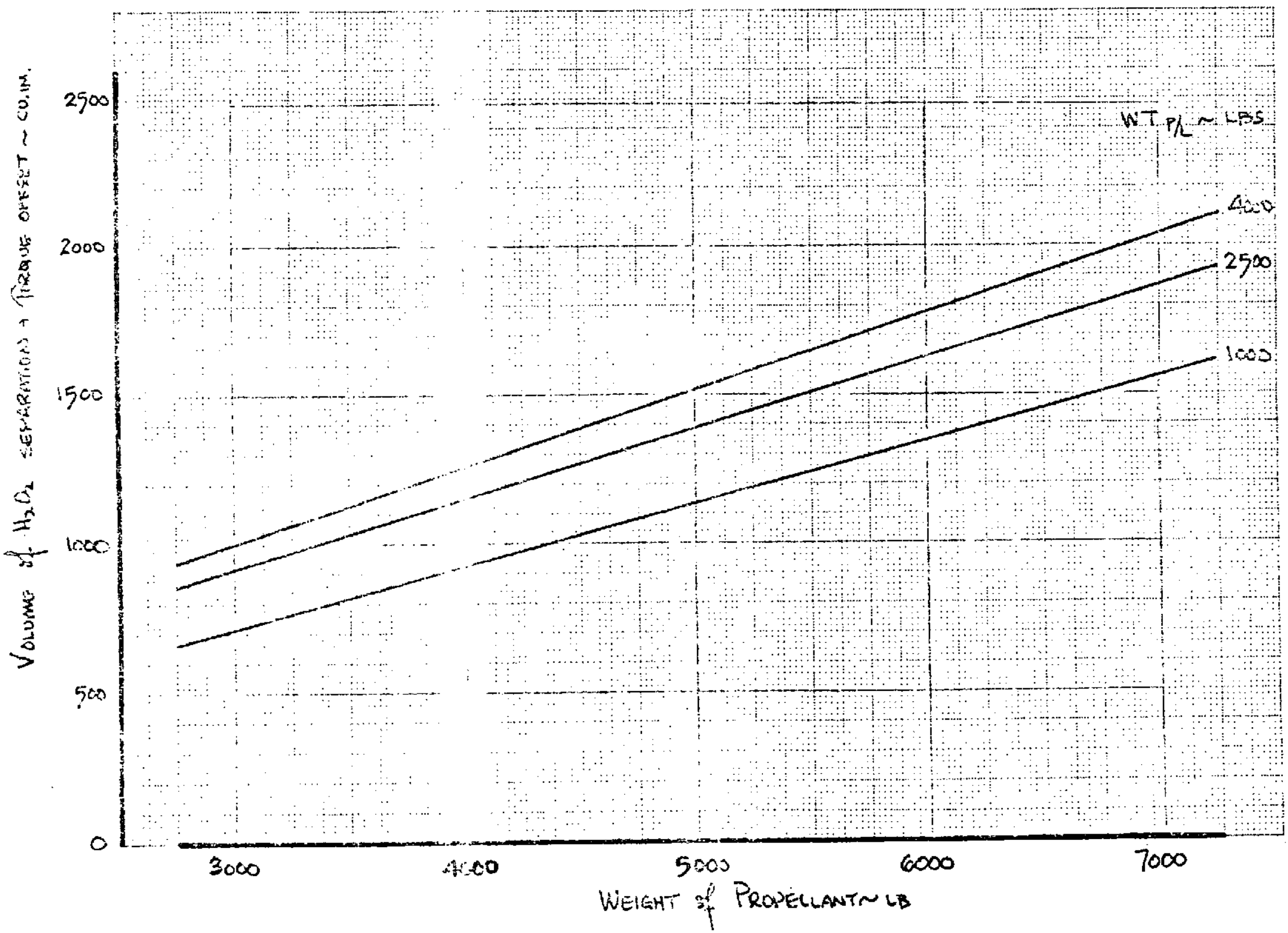


FIGURE 2.2.3-17

HEUS RCS STUDY

TABLE 2.2.3-1

		1	2	3	4	5	6	7	8	9
CONFIGURATION		1	2	3	4	5	6	7	8	9
PAYLOAD WT., LBS		1000	2500	4000	1000	2500	4000	1000	2500	4000
RCS TORQUE OFFSET	THRUST, LB_f	76	95	103	117	144	159	162	192	210
	H_2O_2 WT., LB	22	28	30	35	43	47	48	57	62
	IMPULSE H_2O_2, LB-SEC	2370	2980	3210	3660	4530	4970	5050	6010	6580
HEUS MOTOR	PROPELLANT, LB		3,000			5,000			7,000	
	MAX. THRUST, LB_f		23,000			38,400			53,600	
	AVG. THRUST, LB_f		18,200			30,300			42,400	
	WEB Bo THRUST, LB_f		10,000			16,700			23,300	
	ACTION TIME, SEC					50				
	TOTAL IMPUSLE, LB_f-SEC		909,000			1,515,000			2,121,000	
H_2O_2 WEIGHT FOR SEPARATION - LBS		11	14	15	17	21	23	23	28	30
TOTAL H_2O_2 WT. - LBS		33	42	45	52	64	70	71	85	93
H_2O_2 VOLUME REQUIRED - CU IN		733	920	997	1130	1400	1540	1570	1860	2040

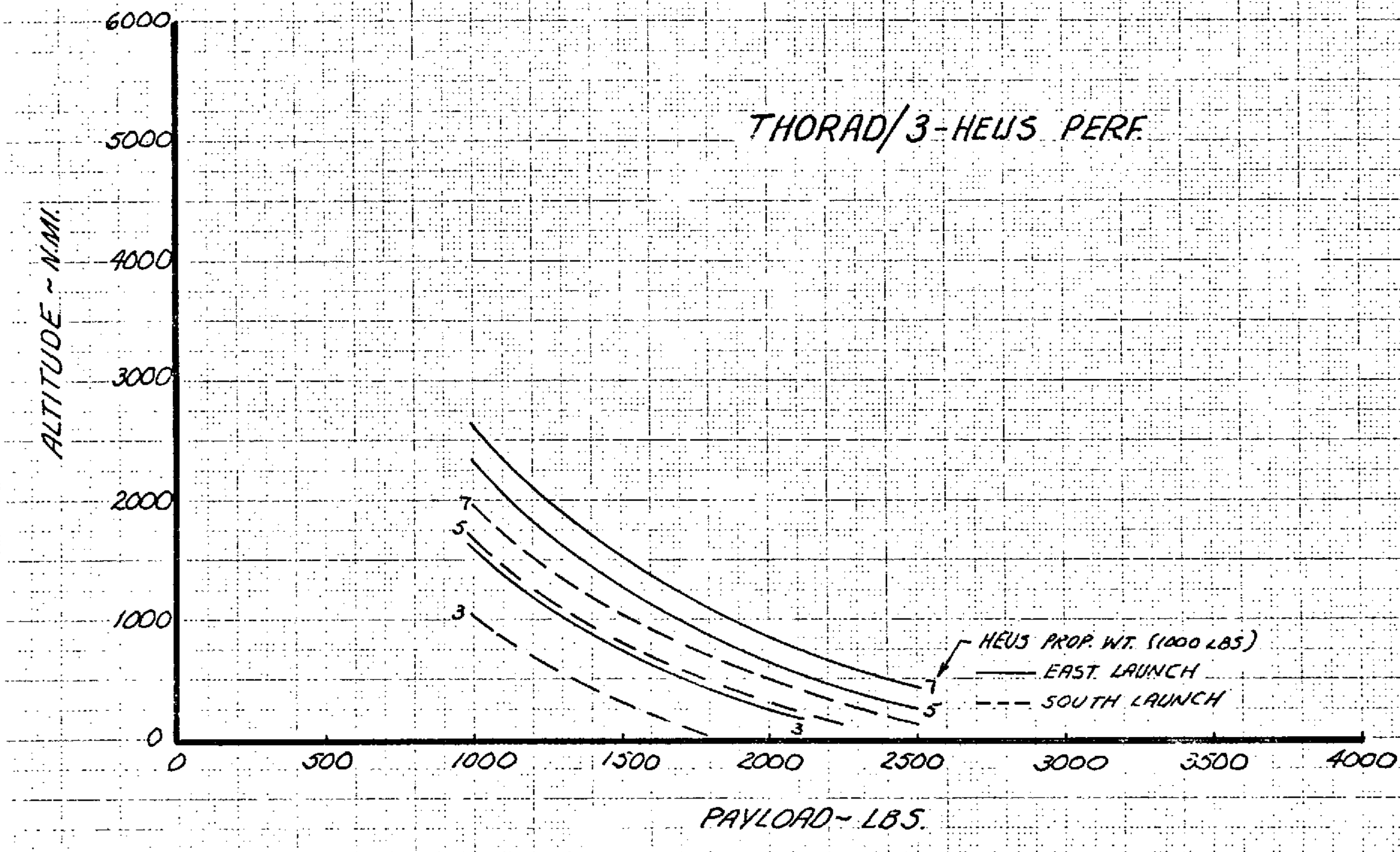

THORAD/3-HEUS PERF.
ALTITUDE ~ N.MI.
6000
5000
4000
3000
2000
1000
0
0
500
1000
1500
2000
2500
3000
3500
4000
PAYLOAD ~ LBS.
7
5
3
HEUS PROP. WT. (1000 LBS)
EAST. LAUNCH
SOUTH LAUNCH

FIGURE 2.2.4-1

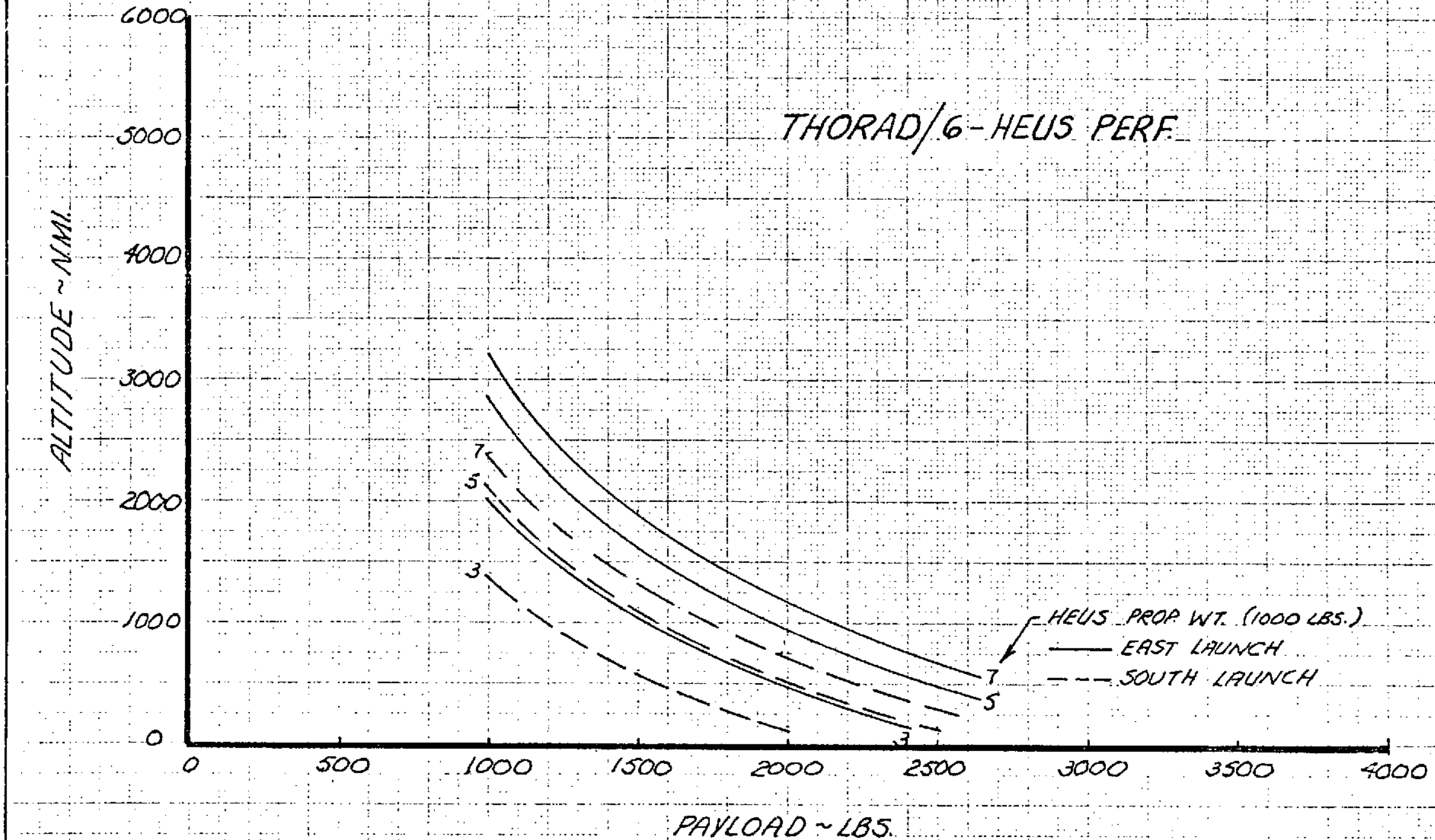

THORAD/6-HEUS PERF.
ALTITUDE ~ N.MI.
6000
5000
4000
3000
2000
1000
0
0
500
1000
1500
2000
2500
3000
3500
4000
PAYLOAD ~ LBS.
HEUS PROP WT. (1000 LBS.)
EAST LAUNCH
SOUTH LAUNCH
7
5
3
7
5
3

FIGURE 2.2.4-2

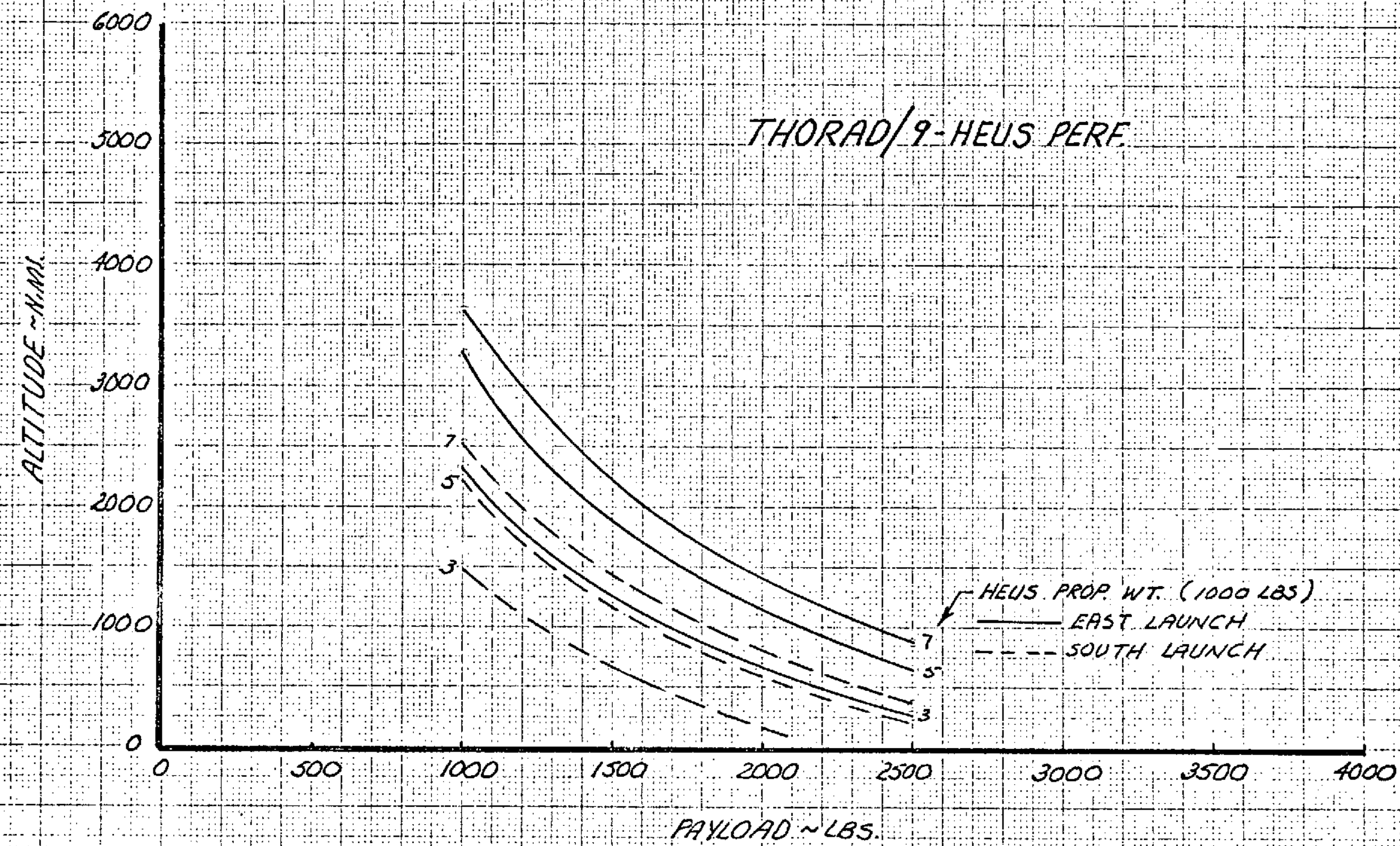

THORAD/9-HEUS PERF.
ALTITUDE ~ N.MI.
6000
5000
4000
3000
2000
1000
0
0
500
1000
1500
2000
2500
3000
3500
4000
PAYLOAD ~ LBS.
HEUS PROP. WT. (1000 LBS)
EAST LAUNCH
SOUTH LAUNCH
7
5
3
7
5
3

FIGURE 2.2.4-3

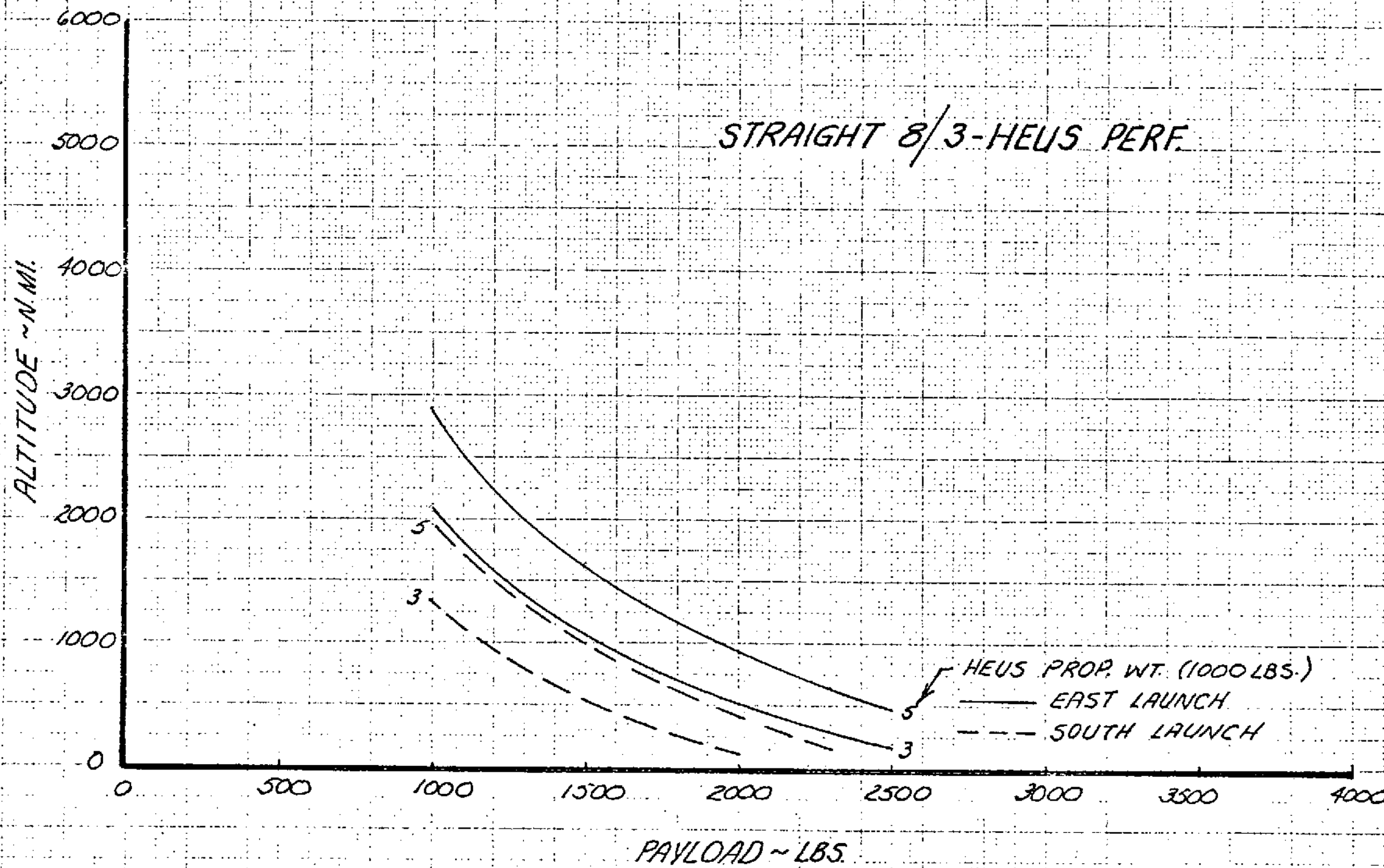

STRAIGHT 8/3-HEUS PERF.
ALTITUDE ~ N.MI.
6000
5000
4000
3000
2000
1000
0
PAYLOAD ~ LBS.
0
500
1000
1500
2000
2500
3000
3500
4000
HEUS PROP. WT. (1000 LBS.)
EAST LAUNCH
SOUTH LAUNCH
5
3
5
3

FIGURE 2.2.4-4

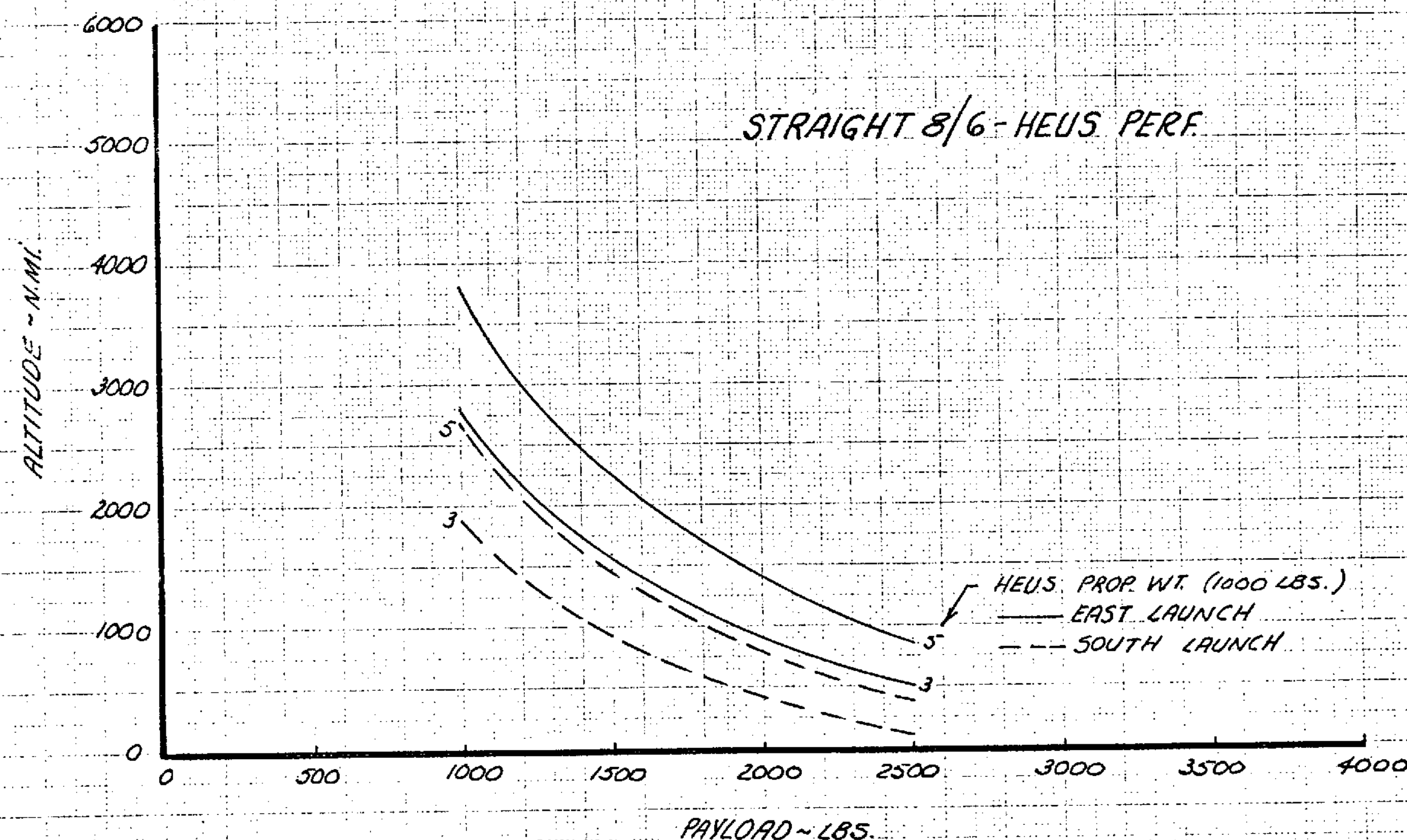

STRAIGHT 8/6-HEUS PERF.
ALTITUDE ~ N.MI.
6000
5000
4000
3000
2000
1000
0
0
500
1000
1500
2000
2500
3000
3500
4000
PAYLOAD ~ LBS.
HEUS PROP. WT. (1000 LBS.)
EAST LAUNCH
SOUTH LAUNCH
5
3
5
3

FIGURE 2.2.2-5

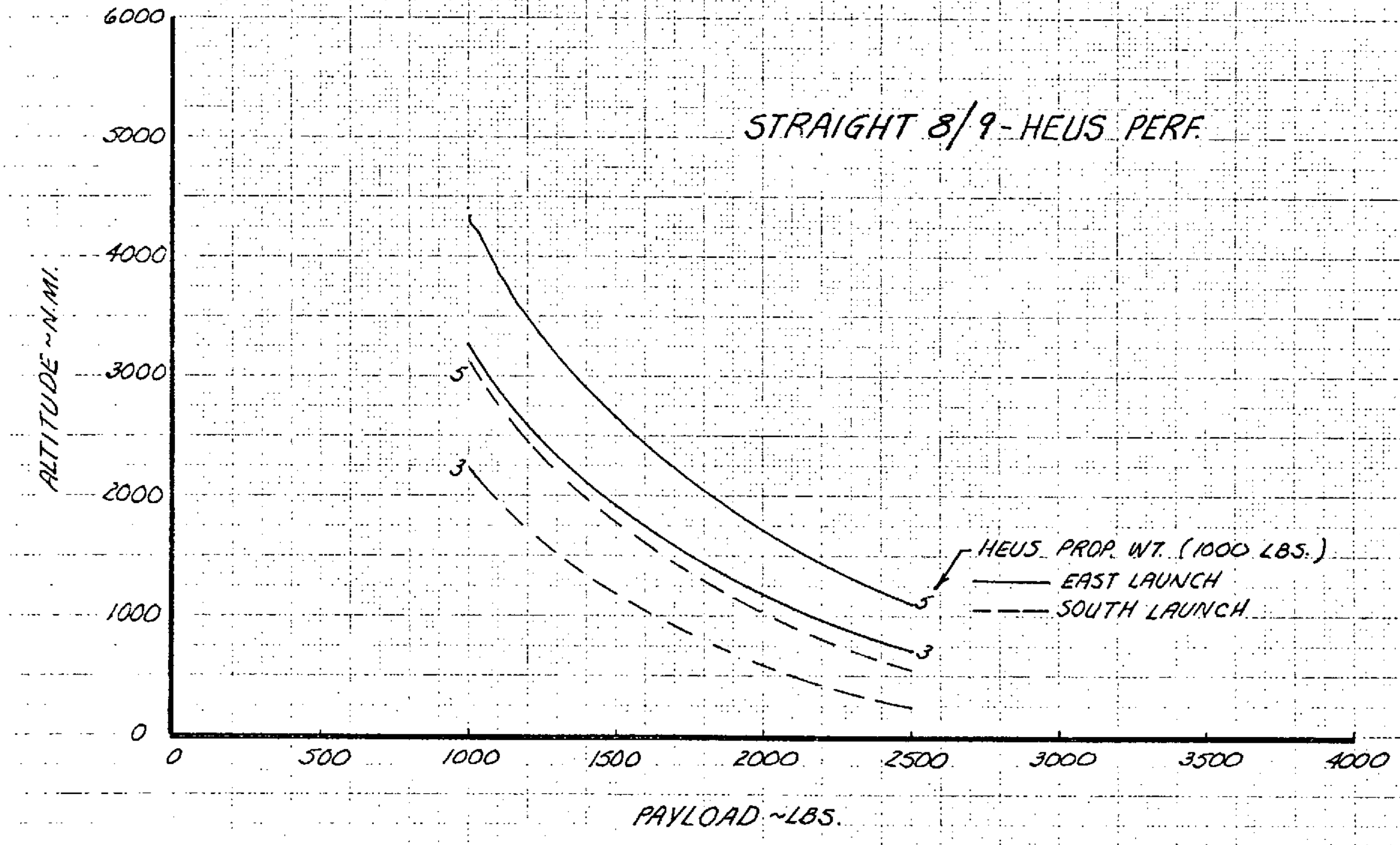
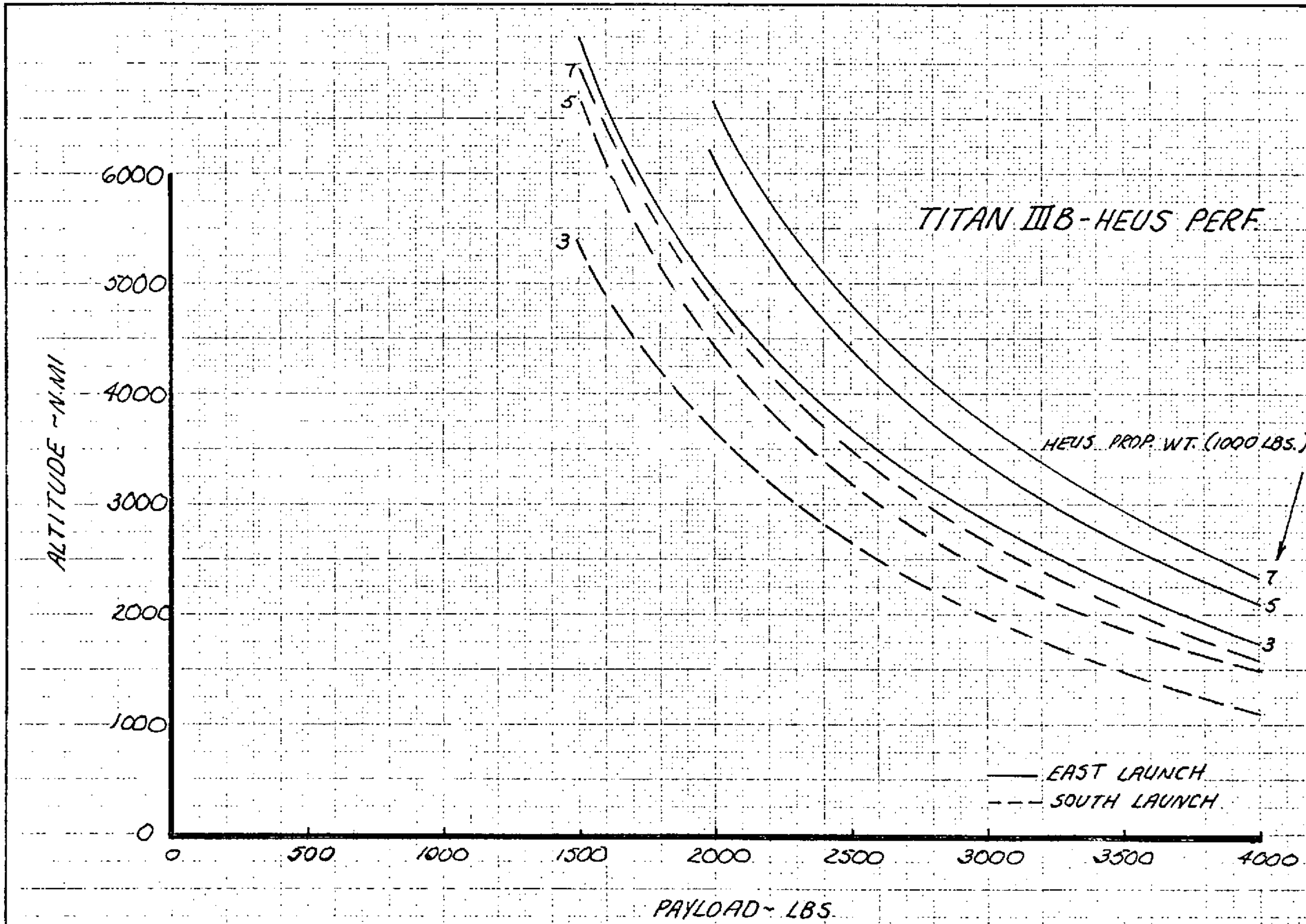


FIGURE 2.2.4-6

SHEET 44

THE BOEING COMPANY

NUMBER D2-116262-1
REV LTR



TITAN IIIB-HEUS PERF.
ALTITUDE ~N.MI
6000
5000
4000
3000
2000
1000
0
PAYLOAD~ LBS
0
500
1000
1500
2000
2500
3000
3500
4000
HEUS PROP. WT. (1000 LBS.)
7
5
3
EAST LAUNCH
SOUTH LAUNCH

FIGURE 2.2.4-7

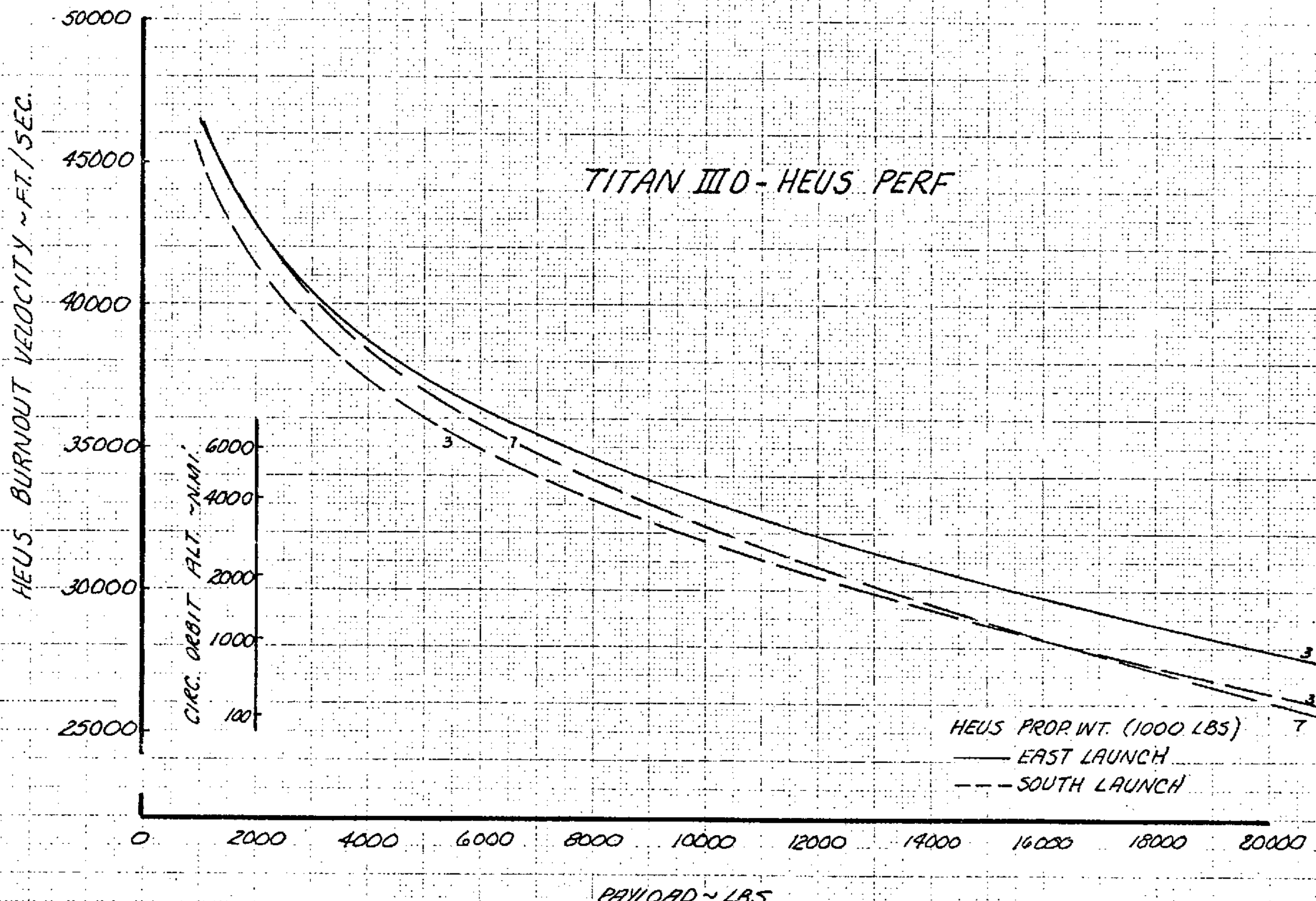

TITAN IIID - HEUS PERF
HEUS BURNOUT VELOCITY ~ FT./SEC.
50000
45000
40000
35000
30000
25000
CIRC. ORBIT ALT. ~ N.MI.
6000
4000
2000
1000
100
3
7
HEUS PROP. WT. (1000 LBS)
EAST LAUNCH
SOUTH LAUNCH
0
2000
4000
6000
8000
10000
12000
14000
16000
18000
20000
PAYLOAD ~ LBS.

FIGURE 2.2.4-8

LAUNCH VEHICLE ASSIGNMENT

3000 LB. HEUS

CURRENT LAUNCH VEHICLE	CURRENT	TITAN III D	TITAN III B	STRAIGHT 8-9	STRAIGHT 8-6	STRAIGHT 8-3	THORAD -3	THORAD -6	THORAD -3	TOTAL
TITAN III D	5									0
ATLAS/CENT	36	12	24							36
DELTA -9	14		9	5						14
DELTA -6	3			1	1				1	3
DELTA -3	75				2			5	68	75
SCOUT	34								33	33
TOTALS	167	12	33	6	3			5	102	161

5000 LB. HEUS

CURRENT LAUNCH VEHICLE	TITAN III D	TITAN III B	STRAIGHT 8-9	STRAIGHT 8-6	STRAIGHT 8-3	THORAD -9	THORAD -6	THORAD -3	TOTAL
TITAN III D									0
ATLAS/CENT	12	12	12						36
DELTA -9		6	3				5		14
DELTA -6						1		2	3
DELTA -3								75	75
SCOUT								33	33
TOTALS	12	18	15			1	5	110	161

7000 LB. HEUS

CURRENT LAUNCH VEHICLE	TITAN III D	TITAN III B	STRAIGHT 8-9	STRAIGHT 8-6	STRAIGHT 8-3	THORAD -9	THORAD -6	THORAD -3	
TITAN III D									0
ATLAS/CENT	12	12		12					36
DELTA -9		6		3				5	14
DELTA -6						1		2	3
DELTA -3								75	75
SCOUT								33	33
TOTALS	12	18		15		1		115	161

TABLE 2.2.4-1

2.2.4 (Cont'd)

Increasing the propellant weight in the HEUS would allow the use of a smaller booster for a given mission. However, the impact of this is relatively small compared to the basic gains made by going to restartable solid stages for the overall mission model.

2.2.5 Selected Stage Configuration

After the mid-term review of the stage configurations and performance analysis described in paragraph 2.2.3 and 2.2.4 respectively, the decision was made to concentrate on configurations using 3000 pound HEUS-RS motors. The motor selected for use was the Hercules motor configuration shown in Hercules Phase II final report No. H250-12-6-7 dated July 1970. (Ref. No. 5). The size of this motor is very close to the feasibility demonstration motor. It contains approximately 500 lbs. more propellant. The launch vehicles selected for use were the 96 inch diameter Thor and Titan IIIB.

2.2.5.1 Configuration Sizing

Stages were designed using the 3000 pound propellant HEUS-RS for use on Titan III's and the 96 diameter Thor and are shown in Figures 2.2.5-1 through 2.2.5-4. The payloads used with these configurations weighed 2400 and 4000 pounds. The total launch configuration is shown in Figure 2.2.5-5. All stages were three axis stabilized and included all the flight subsystems required to launch the payloads including electrical power, telemetry, tracking and command, and attitude control.

The difference in payload weights resulted in two selected stage configurations. The stage for use with 2400 pound payload is hexagonal in cross-section and has a three beam attachment to the launch vehicle adapter.

The stage for use with 4000 pound payload is also hexagonal in cross-section, however, it has a six beam attachment to the launch vehicle adapter to carry the additional load.

Structural sizing was done for both stages and the configurations shown are structurally acceptable for the payloads. A longeron area of 3.0 square inches was selected as an upper limit for which concentrated load redistribution into the adapter section could reasonably be expected. All other stage structural components were sized to be compatible with the longerons. The first mode bending frequency for the stage was calculated to be 14 cps, which is high enough to provide a frequency of about 6 cps for the stack above the booster and be compatible with the booster control system.

The booster adapters are constructed of .125 inch aluminum skin with longitudinal stiffness equivalent to the total longeron area of the stages.

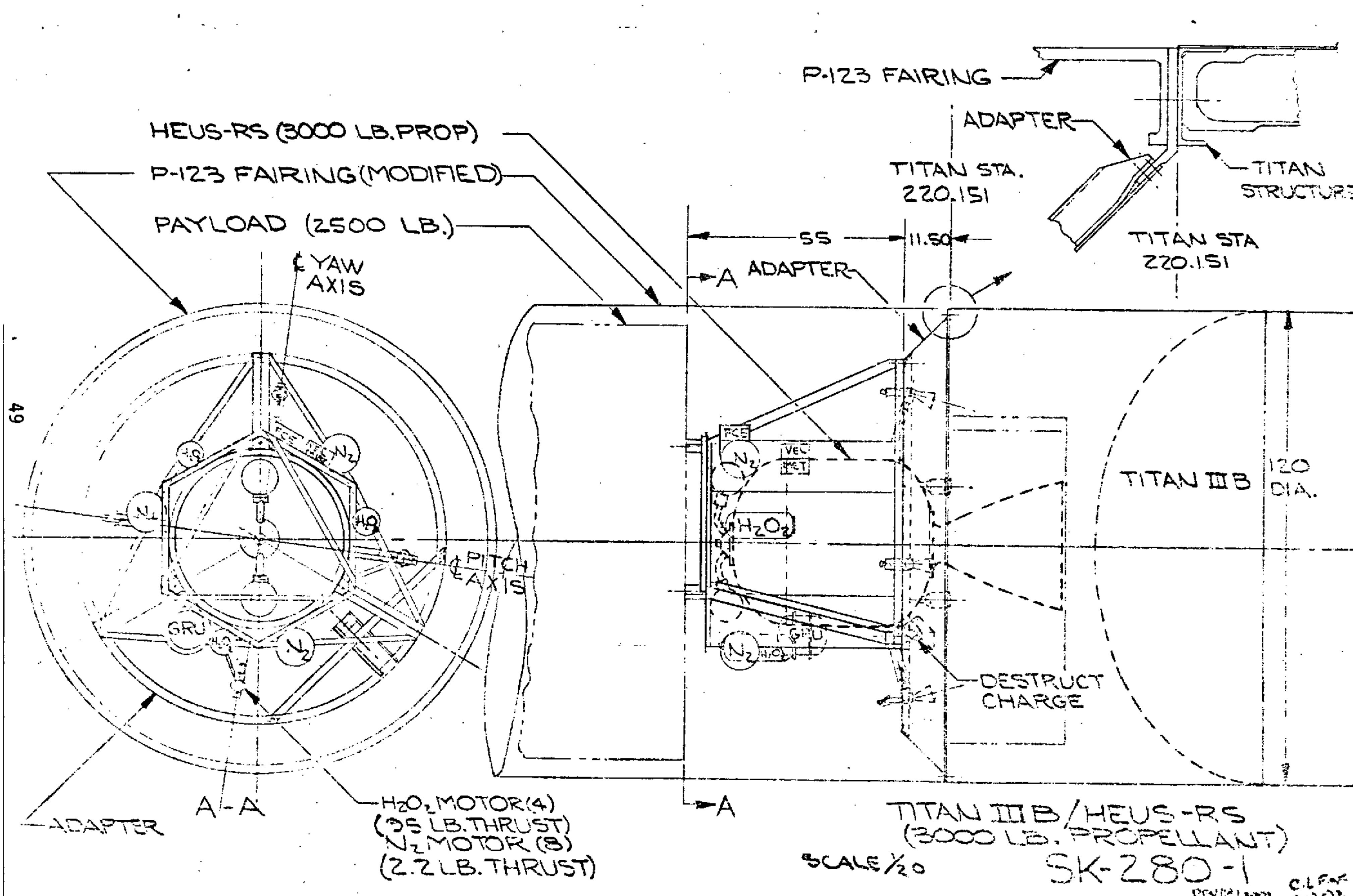
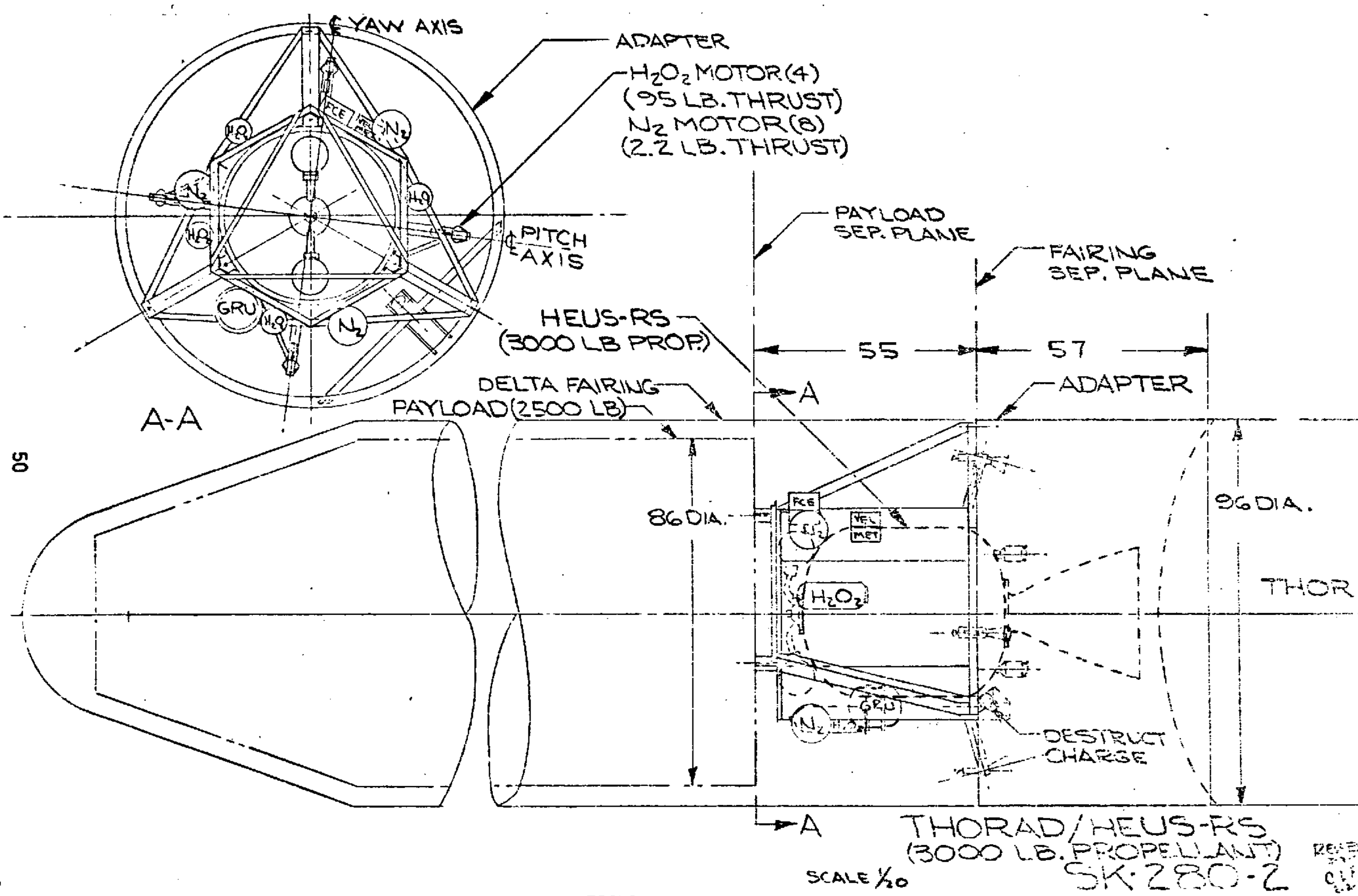

P-123 FAIRING
ADAPTER
TITAN STRUCTURE
TITAN STA. 220.151
TITAN STA 220.151
HEUS-RS (3000 LB. PROP)
P-123 FAIRING (MODIFIED)
PAYLOAD (2500 LB.)
℄ YAW AXIS
55
11.50
A
ADAPTER
FCE
VEC MET
N_2
H_2O_2
GRU
℄ PITCH AXIS
TITAN III B
120 DIA.
DESTRUCT CHARGE
A-A
ADAPTER
H_2O_2 MOTOR (4)
(35 LB. THRUST)
N_2 MOTOR (8)
(2.2 LB. THRUST)
TITAN III B / HEUS-RS
(3000 LB. PROPELLANT)
SCALE 1/20
SK-280-1

FIGURE 2.2.5-1



℄ YAW AXIS
ADAPTER
H2O2 MOTOR (4)
(95 LB. THRUST)
N2 MOTOR (8)
(2.2 LB. THRUST)
FCE
VEL MET
N2
H2O2
GRU
℄ PITCH AXIS
A-A
PAYLOAD SEP. PLANE
FAIRING SEP. PLANE
HEUS-RS
(3000 LB PROP.)
55
57
A
ADAPTER
DELTA FAIRING
PAYLOAD (2500 LB)
86 DIA.
96 DIA.
THOR
DESTRUCT CHARGE
A
THORAD/HEUS-RS
(3000 LB. PROPELLANT)
SK-280-2
SCALE 1/20

FIGURE 2.2.5-2

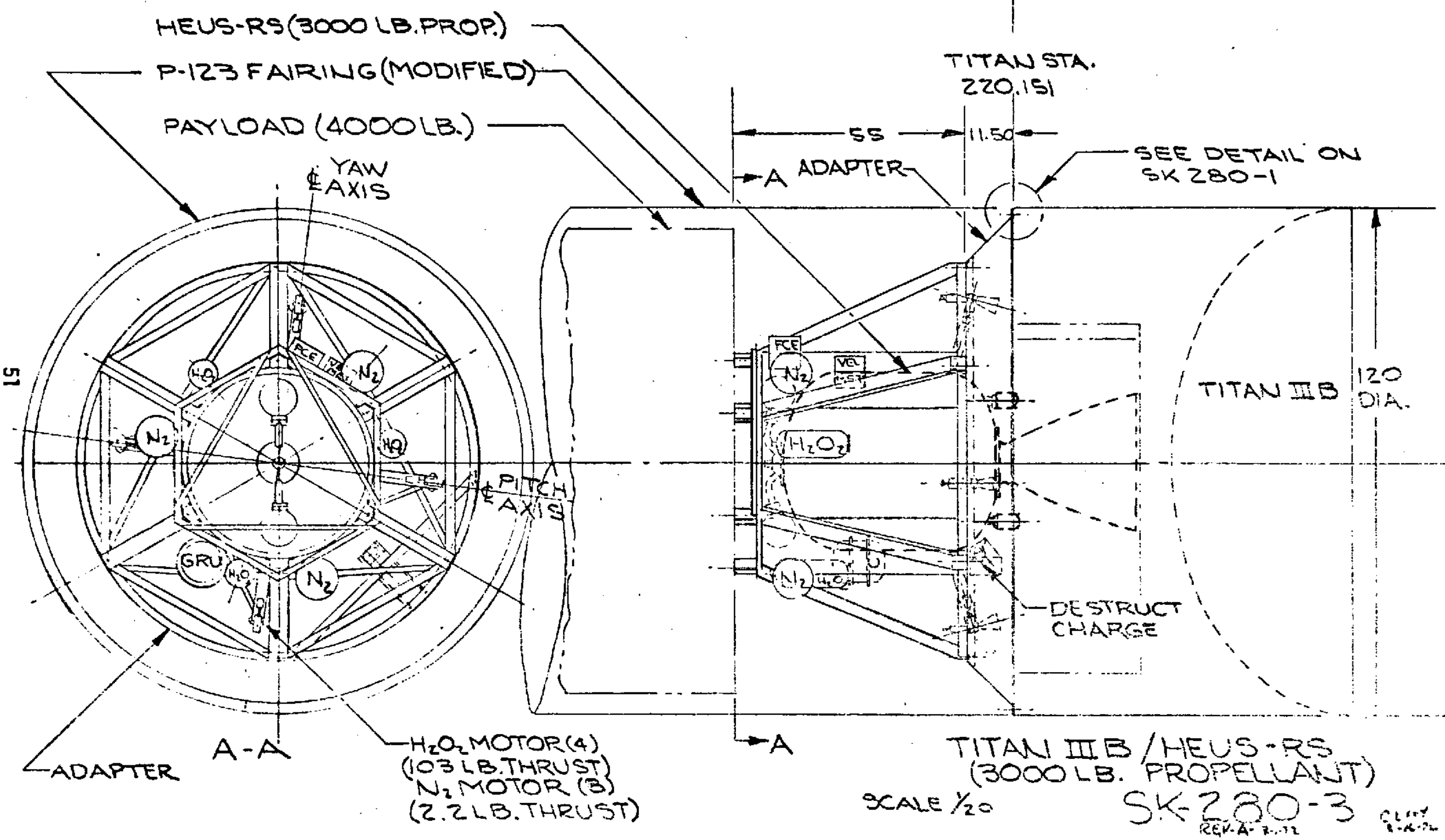
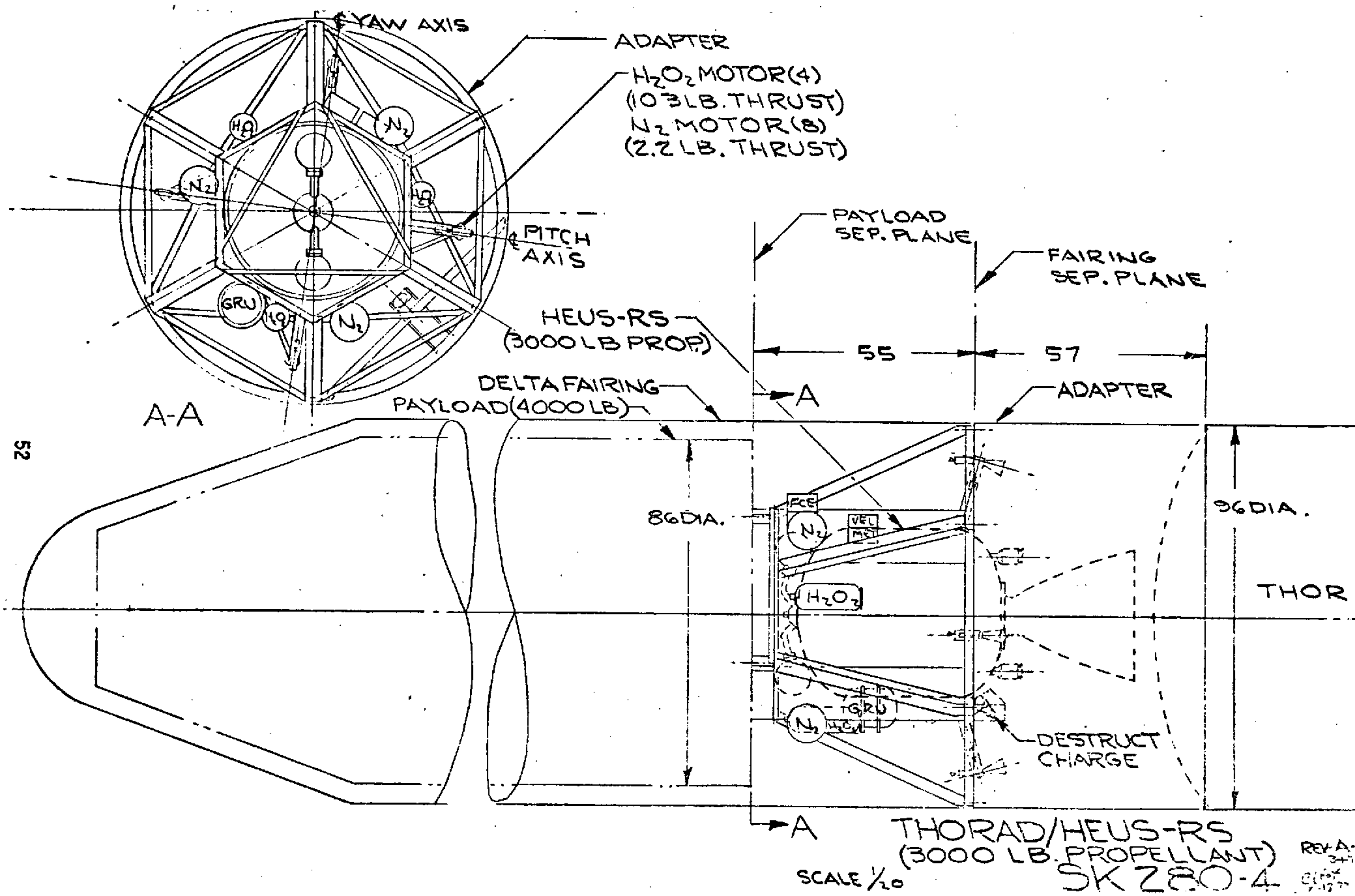

HEUS-RS (3000 LB. PROP.)
P-123 FAIRING (MODIFIED)
PAYLOAD (4000 LB.)
TITAN STA. 220.151
55
11.50
SEE DETAIL ON SK 280-1
A
ADAPTER
YAW AXIS
PITCH AXIS
PCE
VEL
N_2
H_2O_2
GRU
TITAN IIIB
120 DIA.
DESTRUCT CHARGE
ADAPTER
A-A
H_2O_2 MOTOR (4) (103 LB. THRUST)
N_2 MOTOR (8) (2.2 LB. THRUST)
TITAN IIIB / HEUS-RS (3000 LB. PROPELLANT)
SCALE 1/20
SK-280-3

FIGURE 2.2.5-3



℄ YAW AXIS
ADAPTER
H_2O_2 MOTOR(4)
(10 LB. THRUST)
N_2 MOTOR(8)
(2.2 LB. THRUST)
N_2
N_2
N_2
GRU
℄ PITCH AXIS
A-A
HEUS-RS
(3000 LB PROP.)
PAYLOAD SEP. PLANE
FAIRING SEP. PLANE
55
57
A
A
ADAPTER
DELTA FAIRING
PAYLOAD (4000 LB)
86 DIA.
96 DIA.
FCE
VEL MST
H_2O_2
GRU
THOR
DESTRUCT CHARGE
THORAD/HEUS-RS
(3000 LB. PROPELLANT)
SCALE 1/20
SK 280-4
REV A.

FIGURE 2.2.5-4

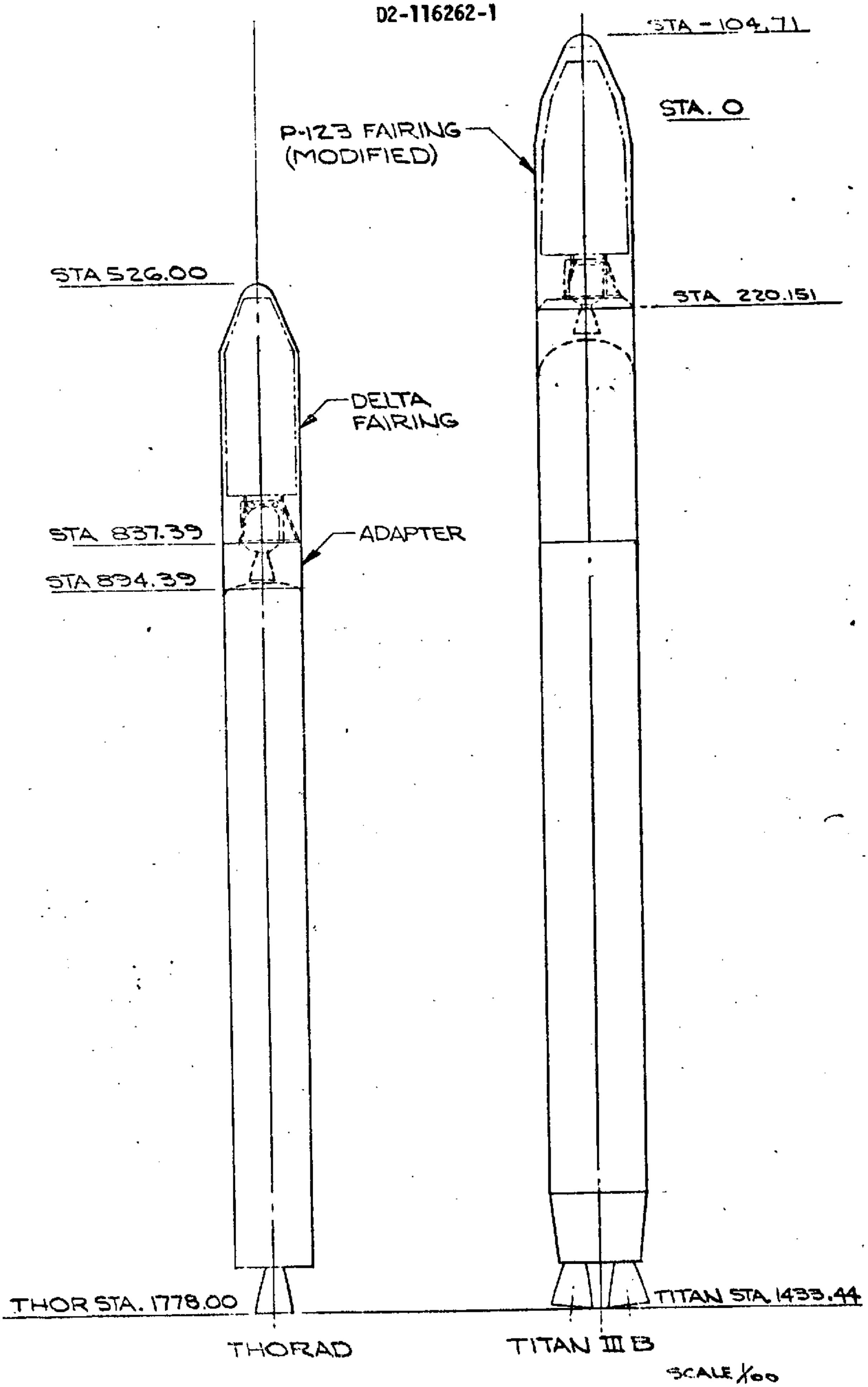

STA -104.71
STA. 0
P-123 FAIRING (MODIFIED)
STA 220.151
STA 526.00
DELTA FAIRING
STA 837.39
ADAPTER
STA 894.39
THOR STA. 1778.00
TITAN STA. 1433.44
THORAD
TITAN IIIB
SCALE 1/100

FIGURE 2.2.5-5

2.2.5.2 Reaction Control System

A Burner II-type reaction control system (RCS) has been sized for the Hercules BE-15B2 HEUS motor and two payload weights; 2500 pounds and 4000 pounds. The selected RCS provides a 1.25 control torque margin with 100 and 108 pound thrust H_2O_2 motors. These H_2O_2 motors are also used for payload/launch vehicle separation. Roll control and coast phase pitch/yaw control can be adequately handled by standard 2.2 pound thrust Burner II N_2 motors. Two pairs are used for roll control and four are used for pitch/yaw control. Four Burner IIA 400 cubic inch H_2O_2 tanks are required and will provide sufficient H_2O_2 for booster separation and attitude control during injection motor burn. Excess H_2O_2 is available for vernier control of burn-out velocity if required. A pair of standard Burner II N_2 tanks will provide the required N_2 for H_2O_2 tank pressurization and roll control during injection motor burn. One pound of N_2 at rated thrust and 3.44 pounds of N_2 in blowdown remains for vehicle control during coast. Table 2.2.5-1 summarizes the H_2O_2 and N_2 RCS data while Table 2.2.5-2 summarizes the HEUS BE-15B2 solid motor performance data used in sizing the RCS. Figures 2.2.5-6 and -7 present the calculated H_2O_2 and N_2 upsetting torques that will occur during the solid motor burn. H_2O_2 and N_2 motor torque capability is also shown. Adequate control margin is provided.

Due to manufacturing and assembly tolerances, vehicle c.g., vehicle center line, and thrust axis will not be in exact alignment. An upsetting torque will be developed. Possible upsetting torque factors include -

1. Payload lateral c.g. uncertainty
2. Stage lateral c.g. uncertainty
3. Payload-to-stage mating
4. Payload-to-stage structural deflection
5. Motor-to-stage mating
6. Motor c.g. offset
7. Motor c.g. excursion
8. Nozzle centerline offset
9. Lateral thrust displacement
10. Angular thrust mis-alignment
11. Expendables offset
12. Expendables Height Differential

Payload and stage lateral c.g. uncertainty combined with the solid motor angular thrust mis-alignment usually constitute approximately 95% of the total upsetting torque. Figure 2.2.5-8 shows these upsetting torque factors. Because the HEUS solid motor thrust varies with time, and as the total vehicle c.g. shifts axially with time, the upsetting torque also varies with time. As the solid motor thrust-time history plays a major role in the RCS sizing calculations, it is repeated here as Figure 2.2.5-9. The neutral thrust-time trace of the BE-15C1 solid motor is shown for comparison (growth version - 3109 vs. 2926 pound VKT propellant). The regressive thrust characteristics of the BE-15B2 motor limits vehicle acceleration to less than 5 g's as shown in Figure 2.2.5-10. Motor c.g. travel and the motor expended weight history is shown in Figure 2.2.5-11. A 260-pound structure and equipment assembly weight (less motor) was assumed for both the 2500 and 4000 pound payload configurations. The effect of motor c.g. travel on vehicle c.g. shift was calculated for both payloads. The vehicle c.g. moves approximately 47

TABLE 2.2.5-1

RCS DATA

H_2O_2 SYSTEM - PITCH/YAW CONTROL

PAYLOAD WEIGHT LBS	2500	4000
H_2O_2 MOTOR THRUST - LB_f	100	108
NUMBER OF MOTORS	4	4
CONTROL TORQUE MARGIN	1.25	1.25
USAGE - BOOSTER SEPARATION - LBS	14.3	15.5
- INJECTION CONTROL - LBS	34.4	36.7
TOTAL REQUIRED - LBS	48.7	52.2
VOLUME REQUIRED - IN^3	974	1044
NUMBER OF TANKS REQUIRED	4	4
TANK SIZE - IN^3	400	400
WT OF H_2O_2 LOADED PER TANK - LBS	17.2	17.2
TOTAL LOADED INTO TANKS - LBS	69.8	69.8
TOTAL AVAILABLE - LBS	68.0	68.0
AMOUNT REMAINING - LBS	19.3	15.8
WT. MARGIN = AVAILABLE/REQUIRED	1.40	1.30

N_2 SYSTEM

ROLL & COAST PITCH/YAW CONTROL

PAYLOAD WEIGHT - LBS	2500	4000
N_2 MOTOR THRUST - LBS	2.2	2.2
NUMBER OF MOTORS REQUIRED - ROLL	4	4
- PITCH/YAW	4	4
CONTROL TORQUE MARGIN	2.00	1.95
USAGE - PRESSURIZE H_2O_2 TANKS - LBS	2.42	2.42
- INJECTION CONTROL - LBS	1.10	1.12
TOTAL REQUIRED - LBS	3.52	3.54
NUMBER OF TANKS REQUIRED	2	2
TANK SIZE - IN^3	340	340
WEIGHT OF N_2 LOADED - LBS	5.85	5.85
REQUIRED AT REGULATED PRESSURE - LBS	3.52	3.54
AMOUNT REMAINING AT REG. PRESSURE - LBS.	1.02	1.00
TRAPPED IN N_2 TANKS - LBS	0.29	0.29
AVAILABLE IN BLOWDOWN MODE - LBS	3.44	3.44
MARGIN @ RATED THRUST	1.93	1.89
@ RATED + BLOWDOWN THRUST	5.05	4.96

TABLE 2.2.5-2

BE-15B2 MOTOR PERFORMANCE DATA

TOTAL IMPULSE - LB. SEC.		889,000
SPECIFIC IMPULSE - LB. SEC/LB		296.33
ACTION TIME - SEC		50
AVERAGE THRUST - LB_f		17,780
MAX. ACCELERATION - g's 2500 LB P/L		4.80
MAX. ACCELERATION - g's 4000 LB P/L		3.74
MOTOR WEIGHTS - LBS	STARTBURN	3314
	PROPELLANT	2926
	INERTS	388
	INERTS EXPENDED	74
	TOTAL EXPENDED	3000
	BURNOUT	314

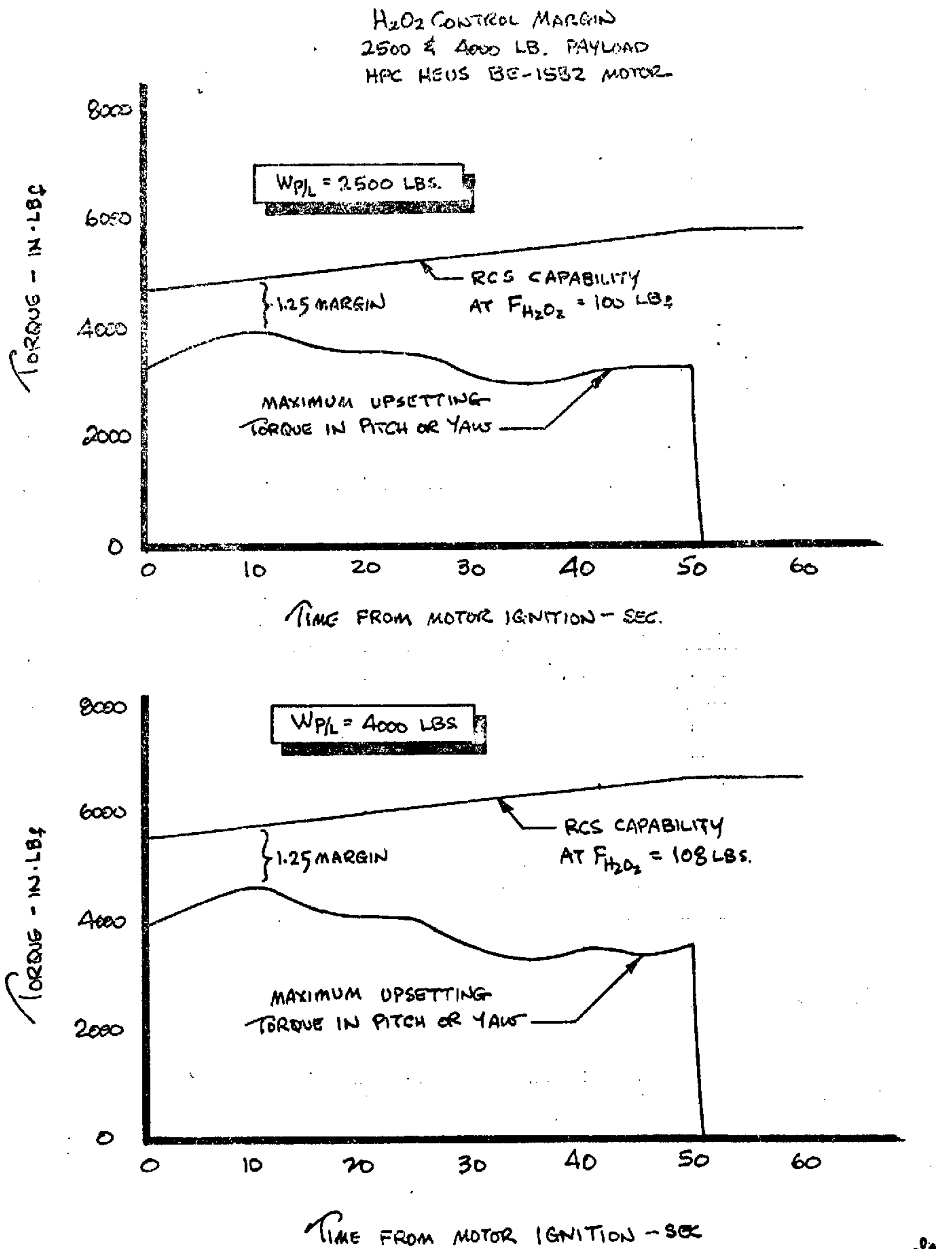

H2O2 CONTROL MARGIN
2500 & 4000 LB. PAYLOAD
HPC HEUS BE-1582 MOTOR
WP/L = 2500 LBS.
RCS CAPABILITY
AT FH2O2 = 100 LBf
1.25 MARGIN
MAXIMUM UPSETTING
TORQUE IN PITCH OR YAW
TORQUE - IN-LBf
TIME FROM MOTOR IGNITION - SEC.
0
2000
4000
6000
8000
0
10
20
30
40
50
60
WP/L = 4000 LBS
RCS CAPABILITY
AT FH2O2 = 108 LBS.
1.25 MARGIN
MAXIMUM UPSETTING
TORQUE IN PITCH OR YAW
TORQUE - IN-LBf
TIME FROM MOTOR IGNITION - SEC

FIGURE 2.2.5-6

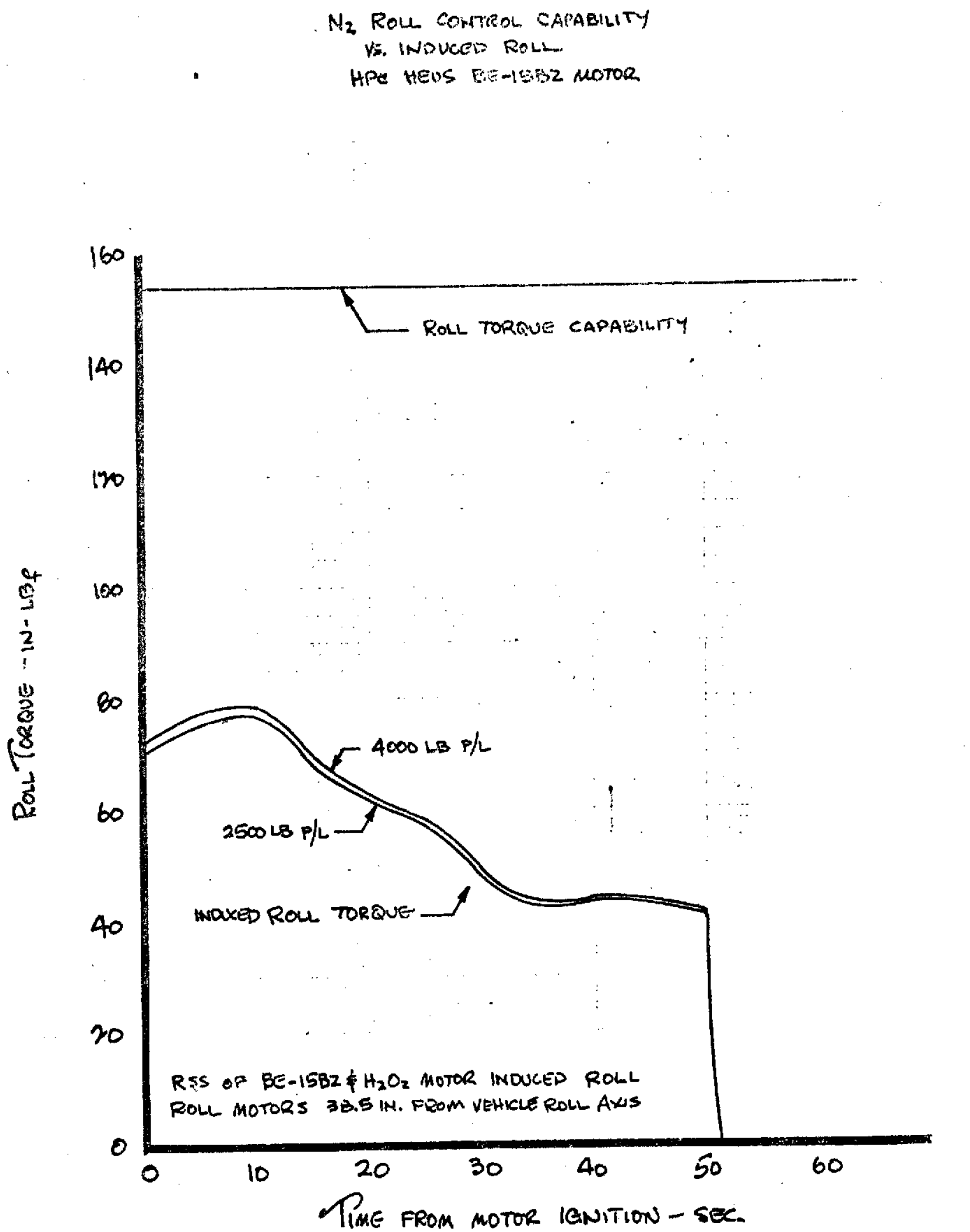

N2 ROLL CONTROL CAPABILITY
VS. INDUCED ROLL
HPC HEDS BE-15B2 MOTOR
ROLL TORQUE CAPABILITY
4000 LB P/L
2500 LB P/L
INDUCED ROLL TORQUE
RSS OF BE-15B2 & H2O2 MOTOR INDUCED ROLL
ROLL MOTORS 38.5 IN. FROM VEHICLE ROLL AXIS
ROLL TORQUE - IN-LBF
TIME FROM MOTOR IGNITION - SEC.
0
20
40
60
80
100
120
140
160
10
30
50

FIGURE 2.2.5-7

FACTORS PRODUCING PITCH/YAW MOMENTS

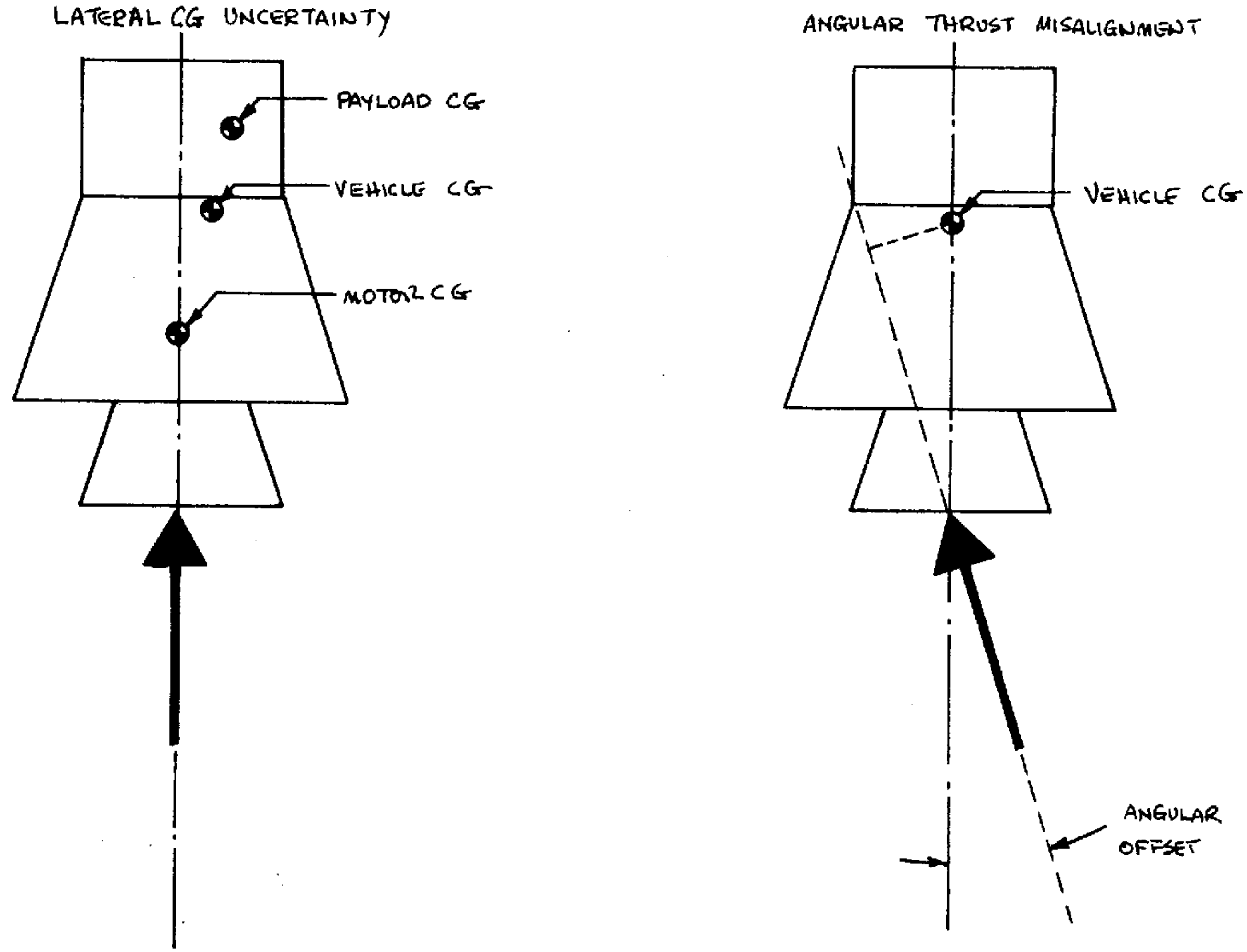


FIGURE 2.2.5-8

D2-116262-1

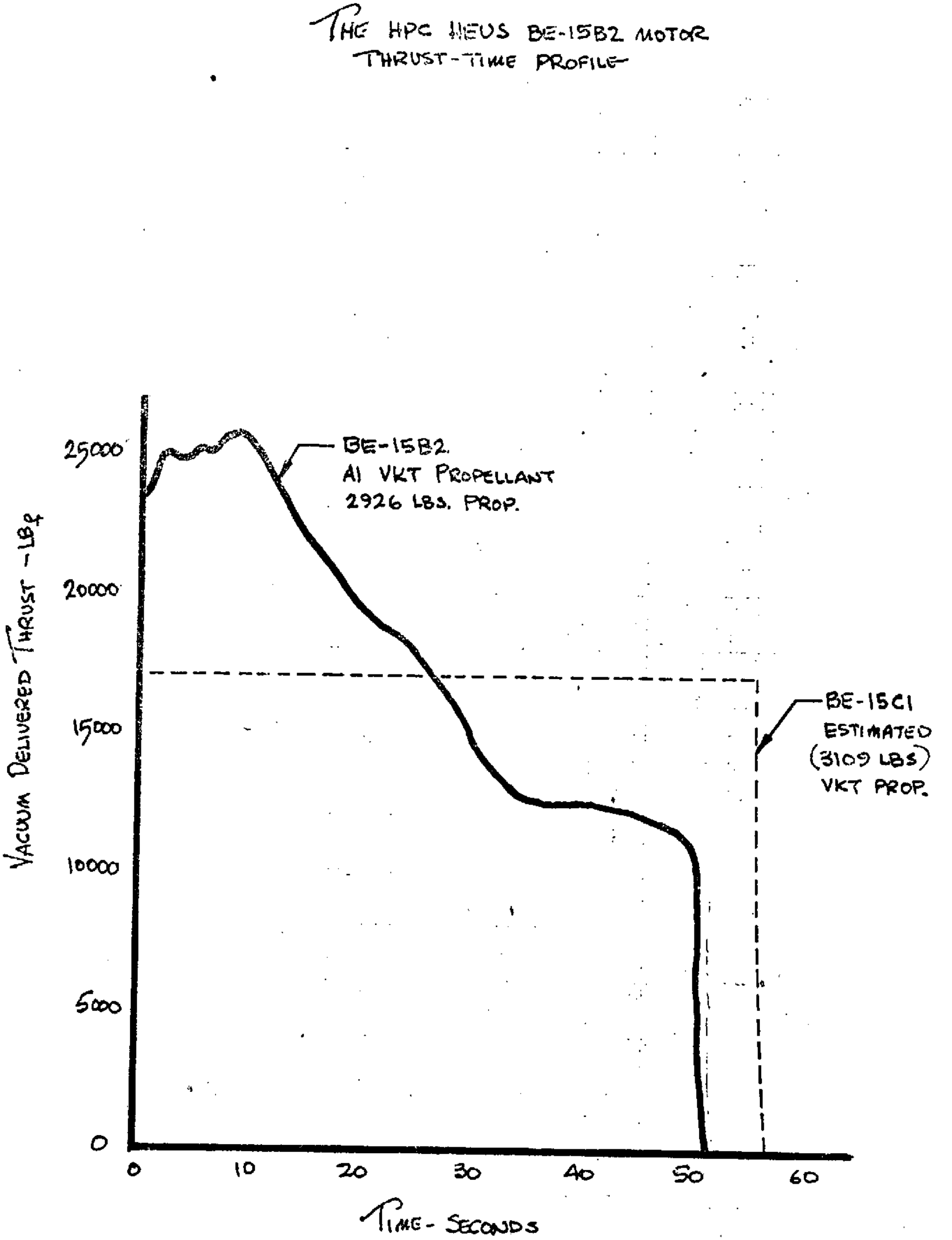

THE HPC NEUS BE-15B2 MOTOR
THRUST-TIME PROFILE
VACUUM DELIVERED THRUST - LBf
25000
20000
15000
10000
5000
0
BE-15B2
Al VKT PROPELLANT
2926 LBS. PROP.
BE-15C1
ESTIMATED
(3109 LBS)
VKT PROP.
0
10
20
30
40
50
60
TIME - SECONDS

FIGURE 2.2.5-9

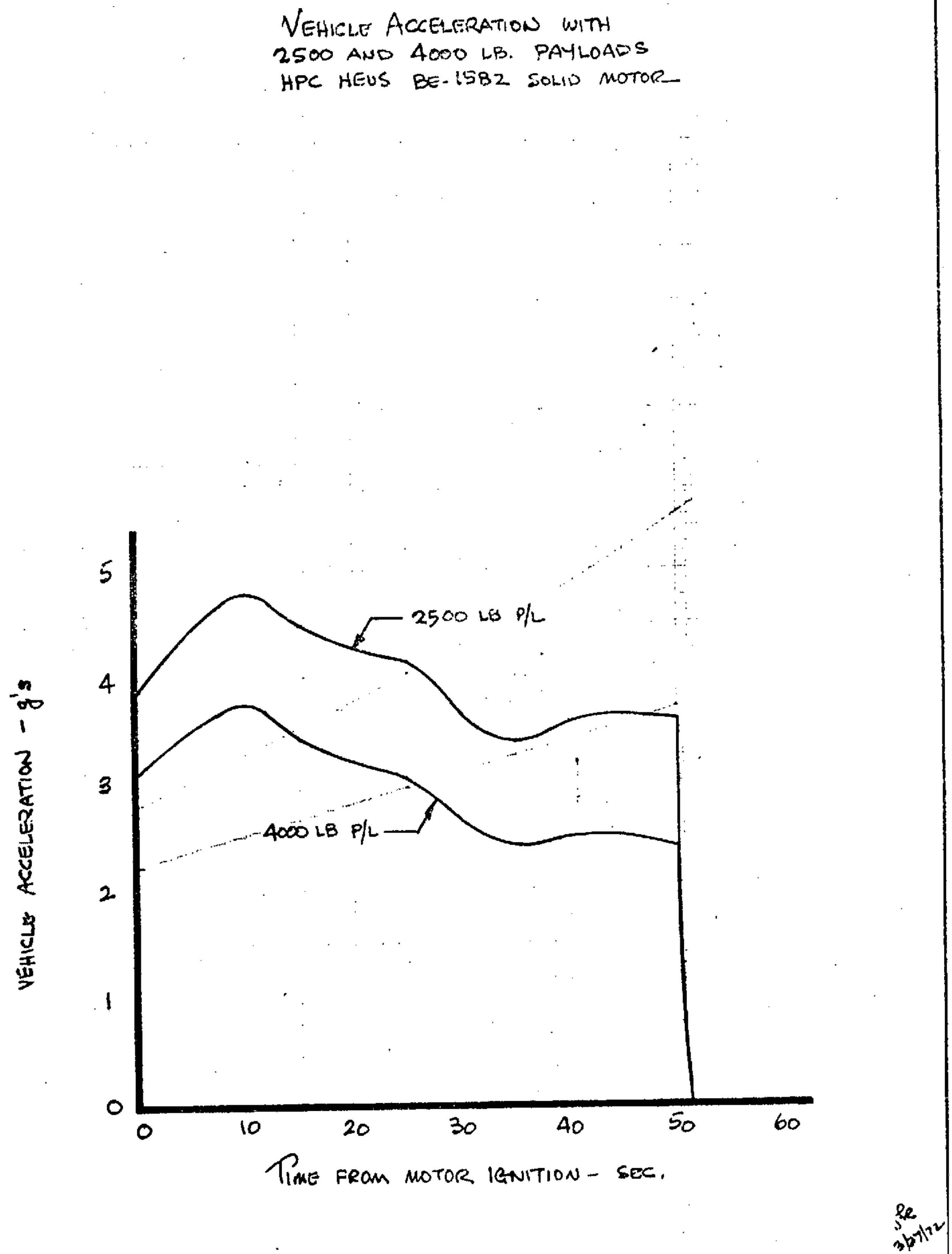


FIGURE 2.2.5-10

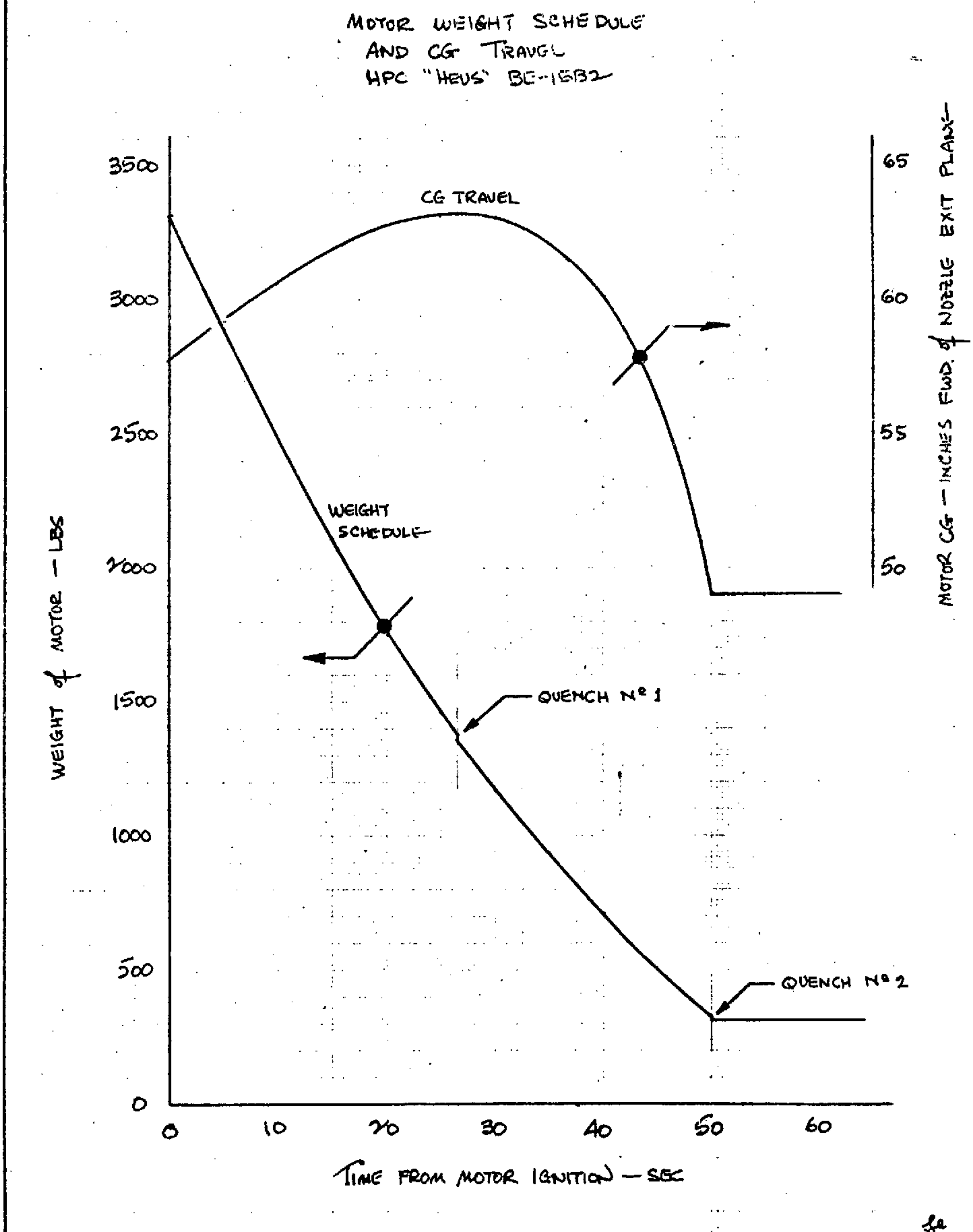


FIGURE 2.2.5-11

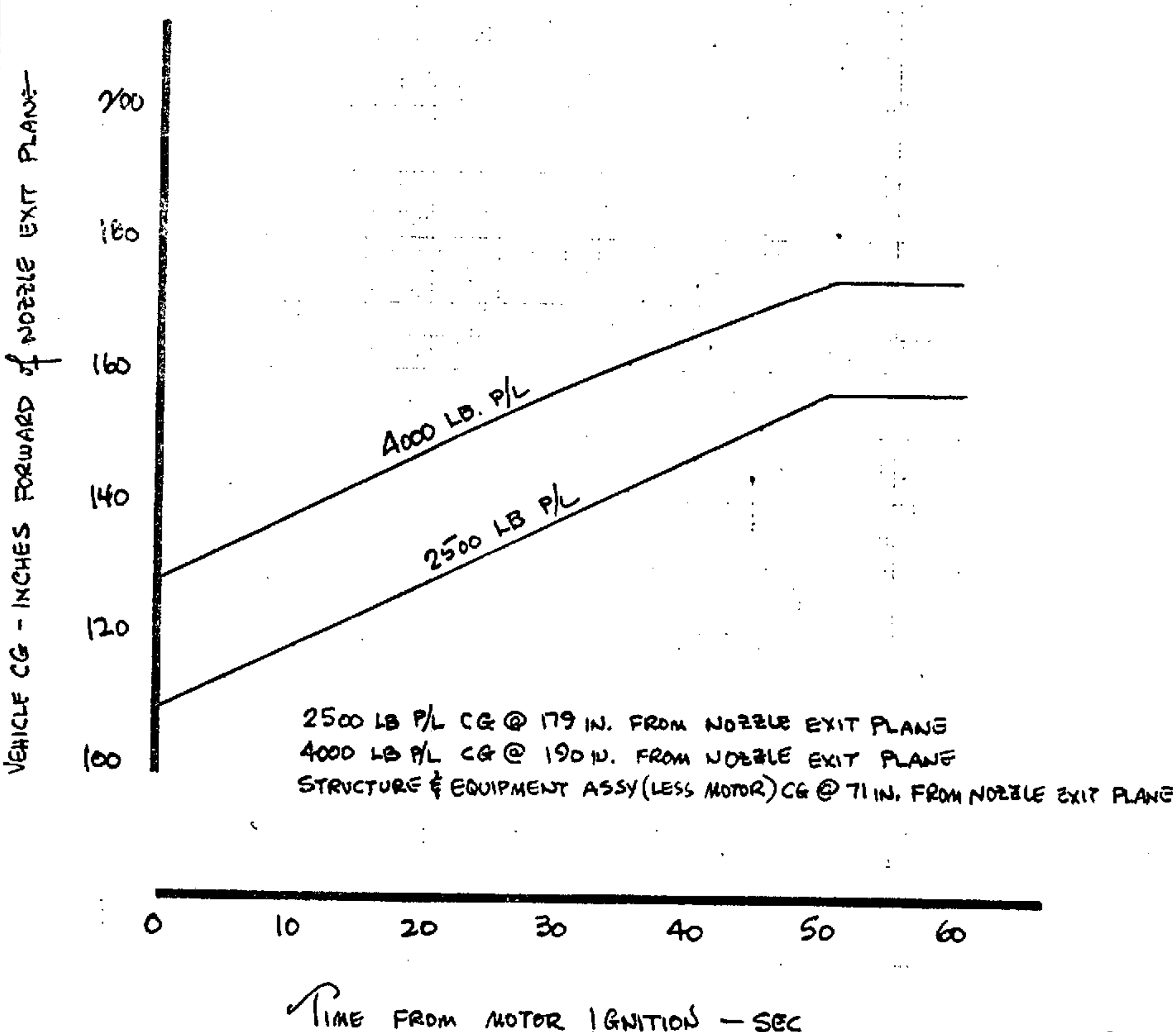
inches forward during motor burn, as shown in Figure 2.2.5-12. The net effective H_2O_2 motor pitch/yaw moment arm, shown in Figure 2.2.5-13, increases as the vehicle moves forward, enhancing the RCS H_2O_2 torque capability. Assuming a nozzle misalignment schedule as shown in Figure 2.2.5-14, typical for a 3000 pound propellant motor, and a 0.20 inch payload lateral c.g. location uncertainty, the maximum upsetting torques in pitch or yaw, shown in Figure 2.2.5-6, is calculated. The pulsed (a normally OFF, pulsed ON, mode is used to control upsetting torques lower than the maximum system capability) H_2O_2 motor thrust required to maintain vehicle control (± 3σ basis) is shown in Figure 2.2.5-15, and is used to size the H_2O_2 tanks. Allowance is also made for the H_2O_2 expended during the 6 second launch vehicle separation burn. The 6 second burn produces the following separation velocities (5 to 6 fps is considered minimum):

Payload Wt - lbs.	ΔV fps
2,500	11.9
4,000	10.3

Four cubic inch H_2O_2 tanks provide a weight margin of 1.40 and 1.30 for the 2500 pound and 4000 pound payloads, respectively.

Roll torque is the net effect of rotary flow through the HEUS motor nozzle and from unavoidable misalignment (± 0.5°) of the H_2O_2 pitch/yaw control motors. Figure 2.2.5-7 shows that the standard 2.2 pound thrust Burner II N_2 roll motors will provide adequate roll control during the HEUS motor firing intervals. Roll control requirements during coast are minimal, as the vehicle is merely oscillating between the attitude error dead-band limits. Figure 2.2.5-16 presents the required N_2 roll motor thrust required to offset the induced roll torque. The area under this curve represents the weight of N_2 required for roll torque control. As shown in Table 2.2.5-1, two 340 cubic inch Burner II N_2 tanks will provide adequate weight margin for injection roll torque control and H_2O_2 tank pressurization. Long duration coast periods (greater than three hours) will require additional N_2 tankage. The two N_2 and four H_2O_2 tanks can be located symmetrically around the stage structure.

VEHICLE CG TRAVEL
WITH MOTOR BURN



3/23/72

FIGURE 2.2.5-12

RCS MOMENT ARM AS INFLUENCED BY CG TRAVEL

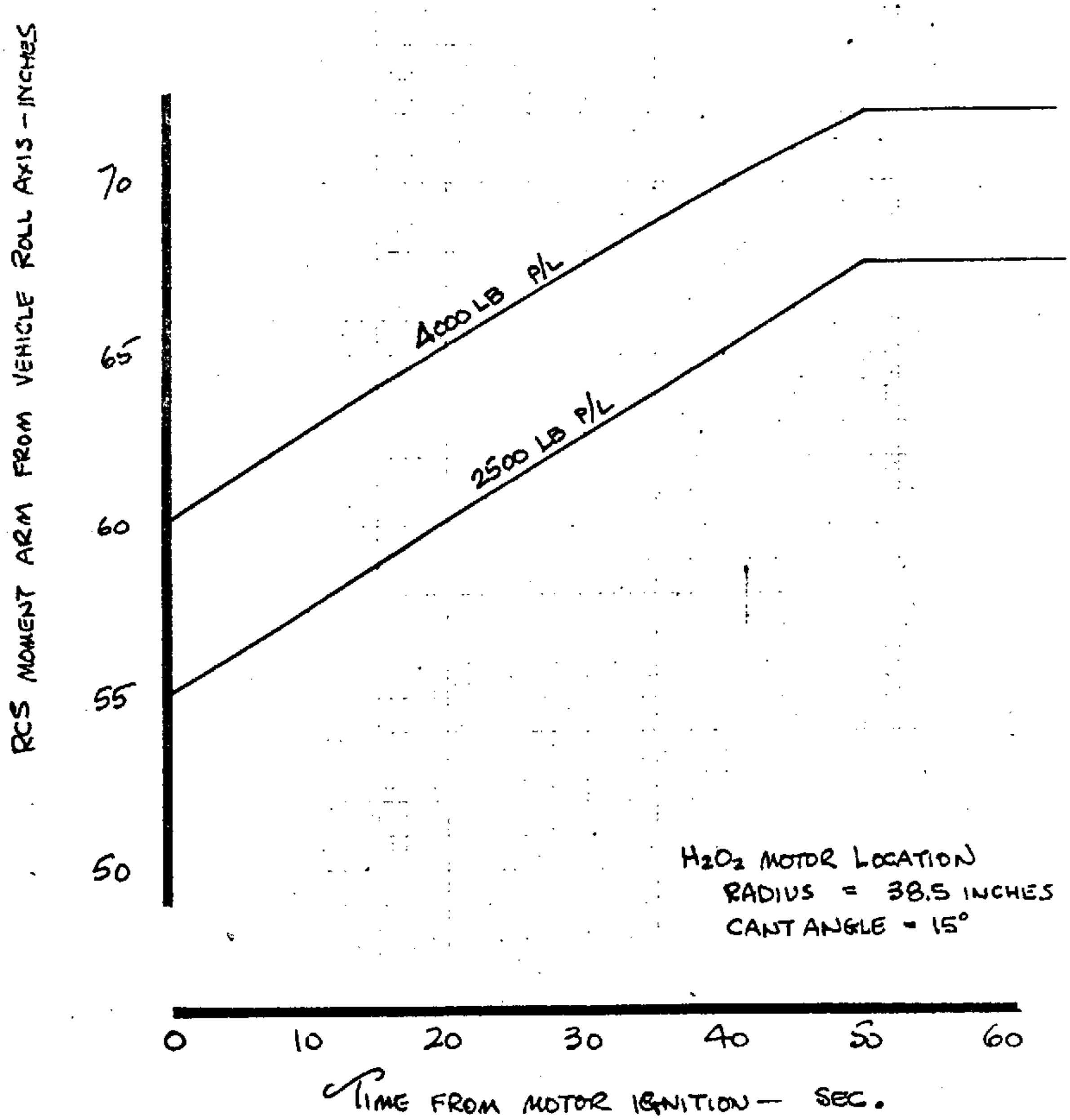


FIGURE 2.2.5-13

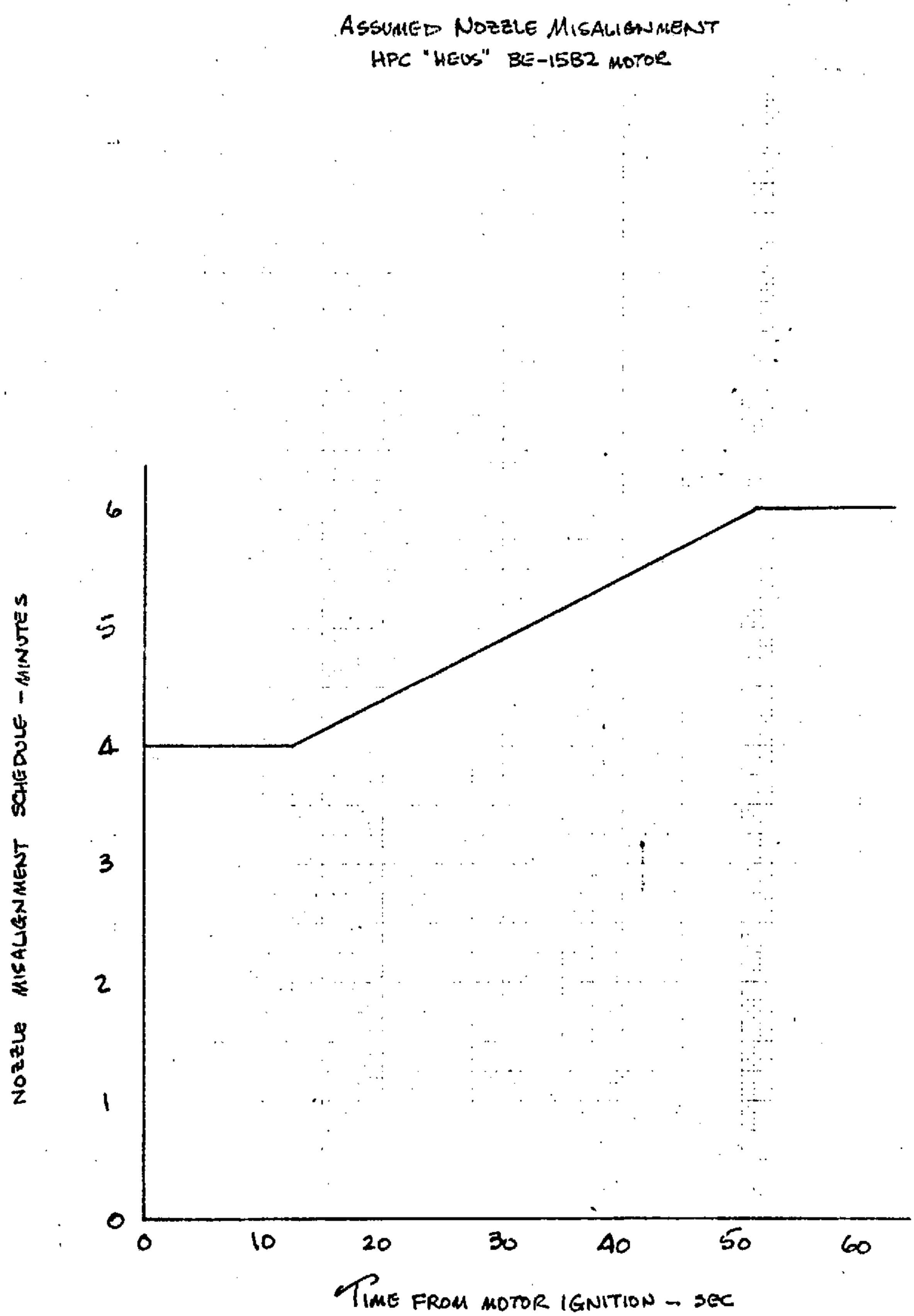


FIGURE 2.2.5-14

RCS REQUIRED H_2O_2 THRUST OUTPUT
HEUS BE-1582 MOTOR

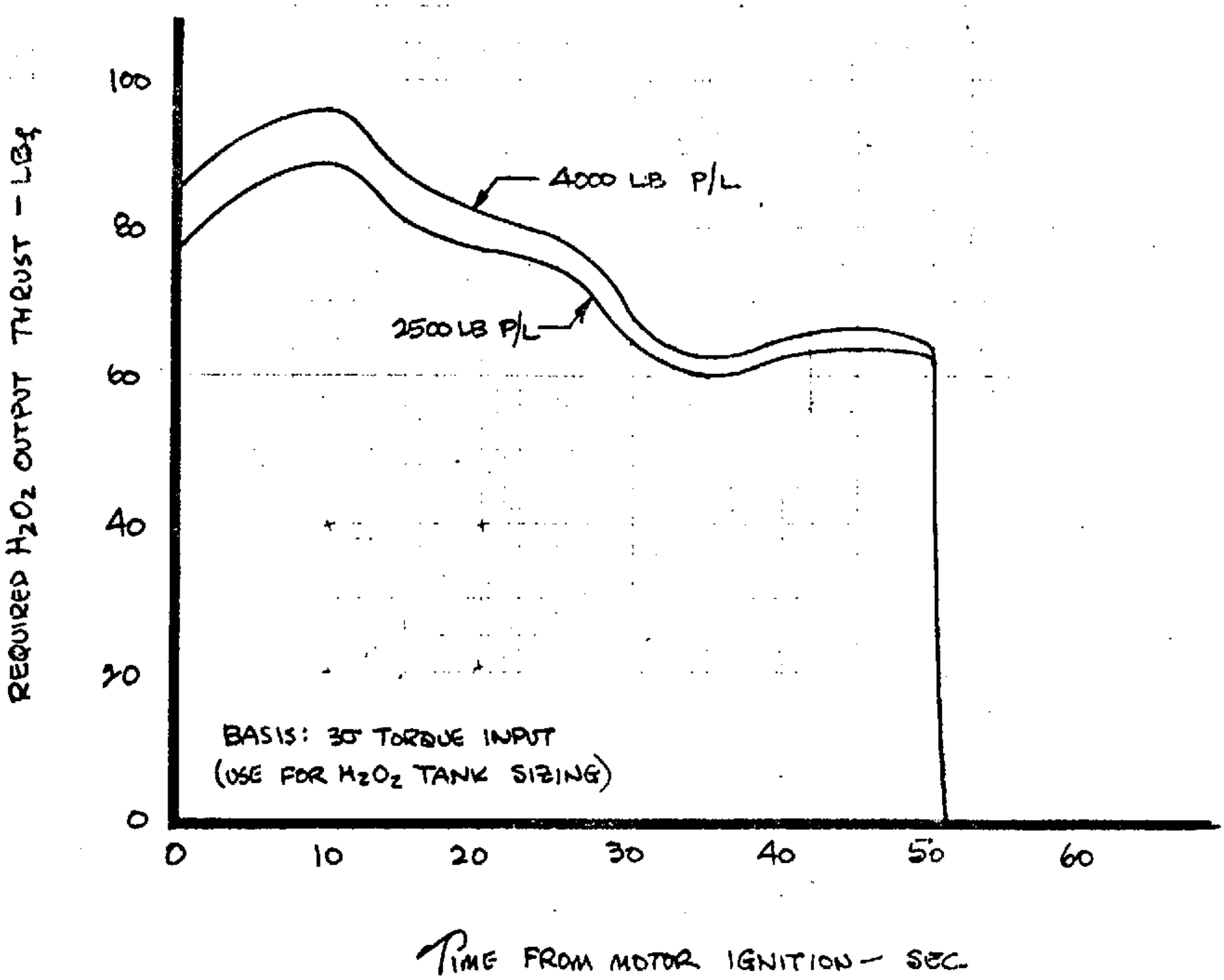


FIGURE 2.2.5-15

REQUIRED N_2 ROLL MOTOR THRUST OUTPUT
HPC HEUS BE-15B2 MOTOR

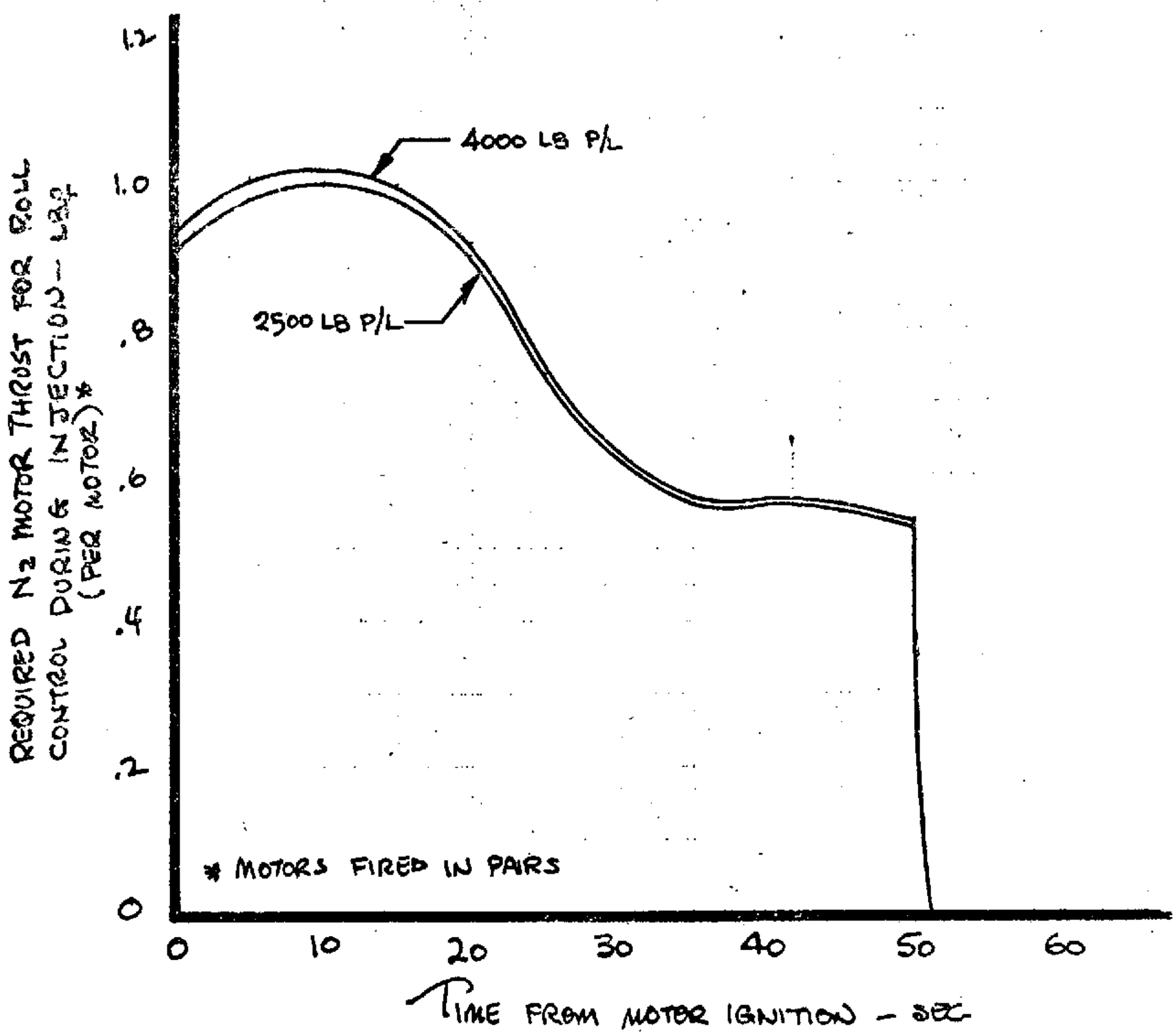


FIGURE 2.2.5-16

2.2.6 Selected Stage Performance

Table 2.2.6-1 shows the performance weight statement for the BE-15B2, TE-M-364-4 and TE-M-364-2 HEUS configurations used in the mission model analysis. The data on the TE-M-364 motors includes the estimated weight for a salt quench system.

Figure 2.2.6-1 shows the ideal velocity capability of these configurations as a function of payload. Variations in the percent of first burn will cause slight variation in the stage capability. The data shown represents the average velocity capability.

TABLE 2.2.6-1

HEUS CONFIGURATION PERFORMANCE

WEIGHT STATEMENT

	BE-15B2	TE364-4	TE364-2
BURNOUT WEIGHT	651.5	401.1	340.7
VERNIER H_2O_2	4.5	12.3	6.3
SOLID BURNOUT	655	413.4	347.0
PROPELLANT WT	2926	2256	1425.0
QUENCH	43	24	15.0
EXPENDED INERT	49	13.5	13.5
CONTROL H_2O_2 & N_2	49	15.3	15.3
TOTAL	3692	2722.2	1815.8

PAYLOAD FAIRINGS	TITAN - 2000 LBS
	THORAD - 1200 LBS
HEUS TO BOOSTER ADAPTER	TITAN - 260 LBS
	THORAD - 500 LBS

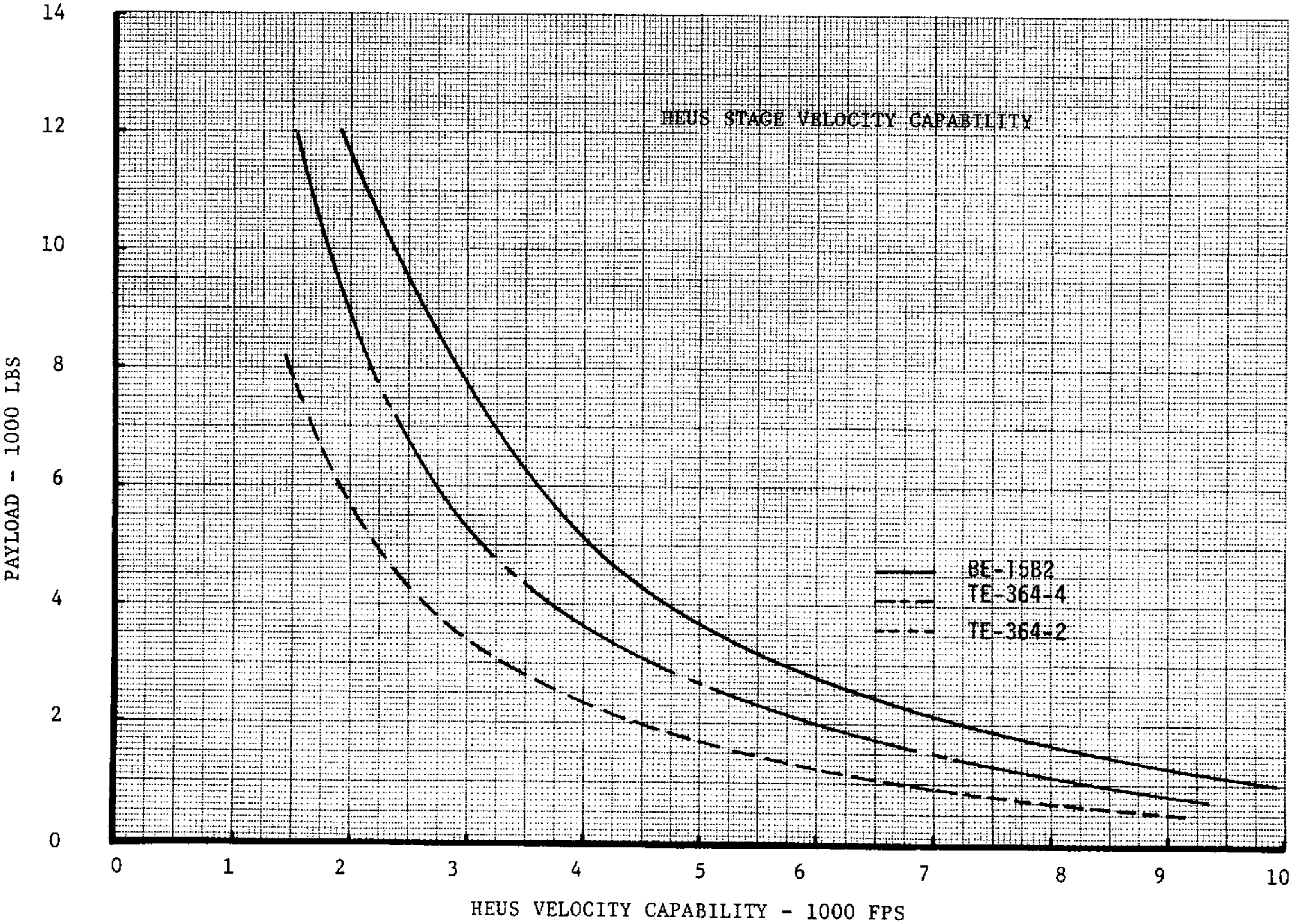

HEUS STAGE VELOCITY CAPABILITY
PAYLOAD - 1000 LBS
14
12
10
8
6
4
2
0
0
1
2
3
4
5
6
7
8
9
10
HEUS VELOCITY CAPABILITY - 1000 FPS
BE-15B2
TE-364-4
TE-364-2

FIGURE 2.2.6-1

2.3 HEUS-RS LAUNCH PROGRAM EVALUATION

2.3.1 Task Requirement

Task No. 3 requires an application of the HEUS performance capability to the mission model defined in Task No. 1.

Payload on orbit for each mission is defined for the HEUS vehicles described in Tasks No. 1 and No. 2. Mission ana-ysis is limited to assurance that the HEUS/BOOSTER combination can meet the mission requirements.

2.3.2 Mission Analysis

General performance data has been developed for the final HEUS configuration and the restartable TE-M-364-2 and TE-M-364-4. These data are presented for the standard Thorad, the "straignt 8" Thorad,the Titan IIIB and the Titan IIID. Data is provided for east launch from ETR and polar and 100^{o} inclination launch from WTR. Many missions in the mission model require sun-synchronous inclinations hence the 100^{o} inclination data. These data approximate sun-synchronous inclinations over the altitude region of interest. Figures 2.3-1 to 2.3-3 show the standard Thorad for the three launch azimuths. The performance gain for this family is greatest with propellant increases in the upper stage. The performance increase from the TE-M-364-2 to the TE-M-364-4 is virtually equivalent to the gain from 3 to 9 strap-ons.

Figures 2.3-4 to 2.3-6 show similar data for the Thorad (straight 8) booster. The percentage of first burn for all the Thorad vehicles falls in the 80% to 99% region. This requirement can be met by the BE-15B2 quench system. The mission applications require two starts and one quench stop, the final stop being burnout of the solid motor. Variations in the impulse of the second burn would be compensated by the H_2O_2 vernier system.

Figures 2.3-7 to 2.3-9 show the Titan IIIB data. This launch vehicle provides an attractive capability for mission requirements in excess of the TAT(9C)DELTA capability.

Figure 2.3-10 shows east and south launch payload capability for the Titan IIID. The Titan IIID somewhat limits the HEUS capability. For example, the BE-15B2 configuration east launch requires less than a 50% burn for altitudes above 475 nm. The percentage first burn reduces to 0, or a single burn at an altitude of 1050 n.m. At altitudes above 1050 n.m. there is insufficient impulse in the HEUS to take advantage of the Titan IIID capability. This limits the capability to the payload attainable by the HEUS when providing the apogee circularization velocity. This results in a requirement to cutoff the Titan IIID early and results in wasting Titan IIID capability. It should be noted, however, that the HEUS provides a significant increase in performance over the basic Titan IIID.

These performance data were applied to the mission model presented in Section 2.1 to determine the impact of a restartable solid motor on NASA applications.

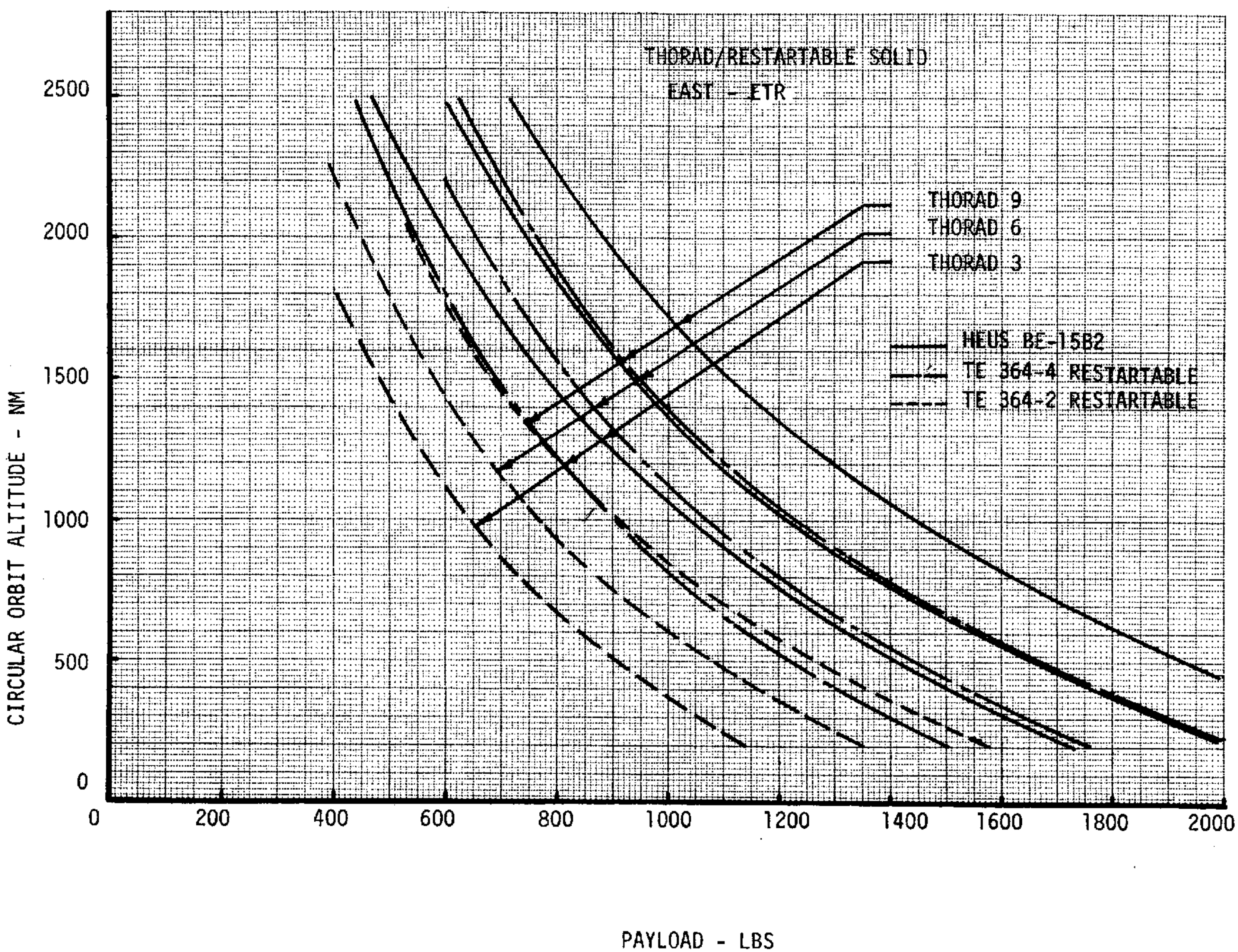

THORAD/RESTARTABLE SOLID
EAST - ETR
THORAD 9
THORAD 6
THORAD 3
HEUS BE-15B2
TE 364-4 RESTARTABLE
TE 364-2 RESTARTABLE
CIRCULAR ORBIT ALTITUDE - NM
0
500
1000
1500
2000
2500
0
200
400
600
800
1000
1200
1400
1600
1800
2000
PAYLOAD - LBS

FIGURE 2.3-1

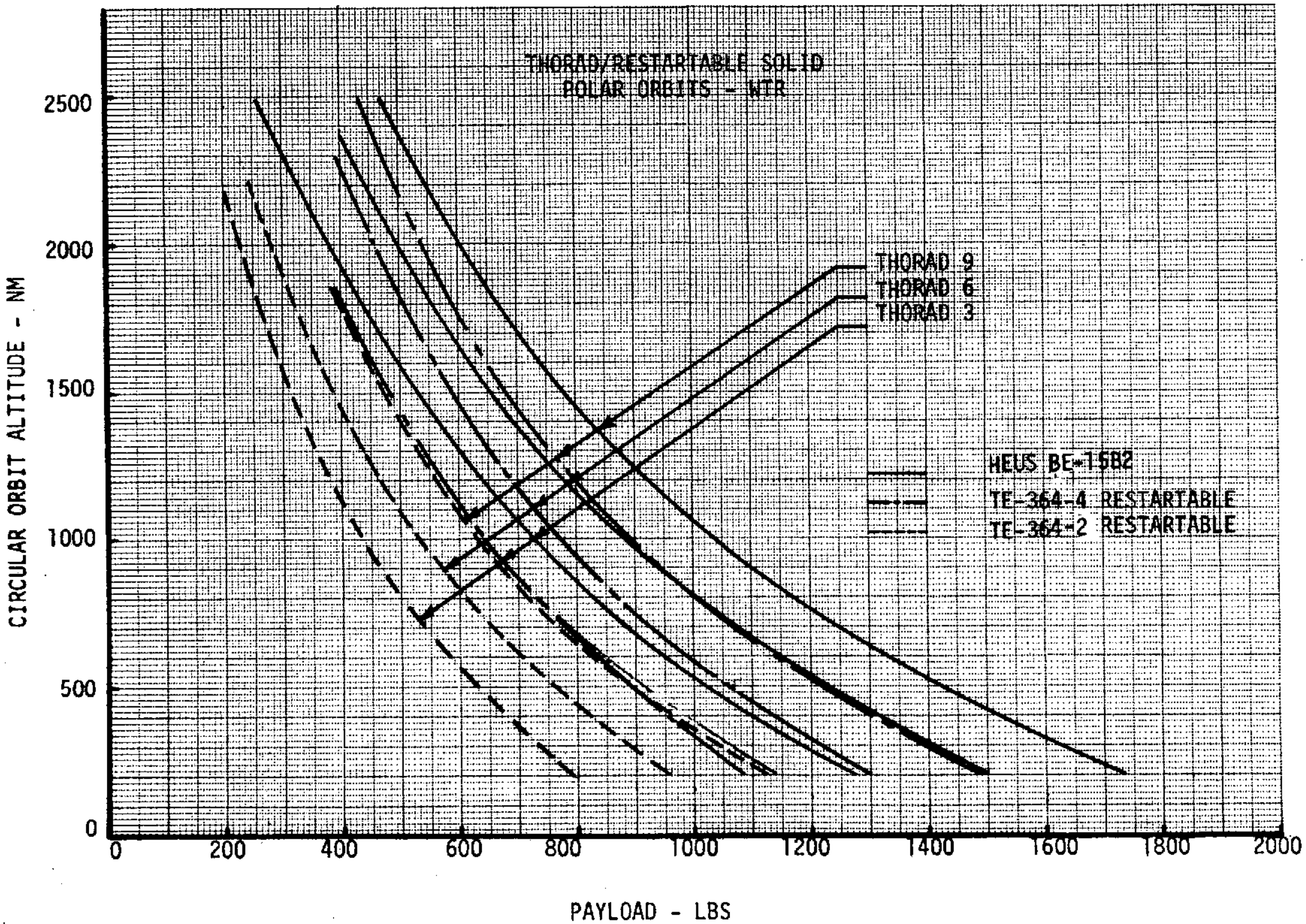

THORAD/RESTARTABLE SOLID
POLAR ORBITS - WTR
THORAD 9
THORAD 6
THORAD 3
HEUS BE-15B2
TE-364-4 RESTARTABLE
TE-364-2 RESTARTABLE
CIRCULAR ORBIT ALTITUDE - NM
PAYLOAD - LBS
0
500
1000
1500
2000
2500
0
200
400
600
800
1000
1200
1400
1600
1800
2000

FIGURE 2.3-2

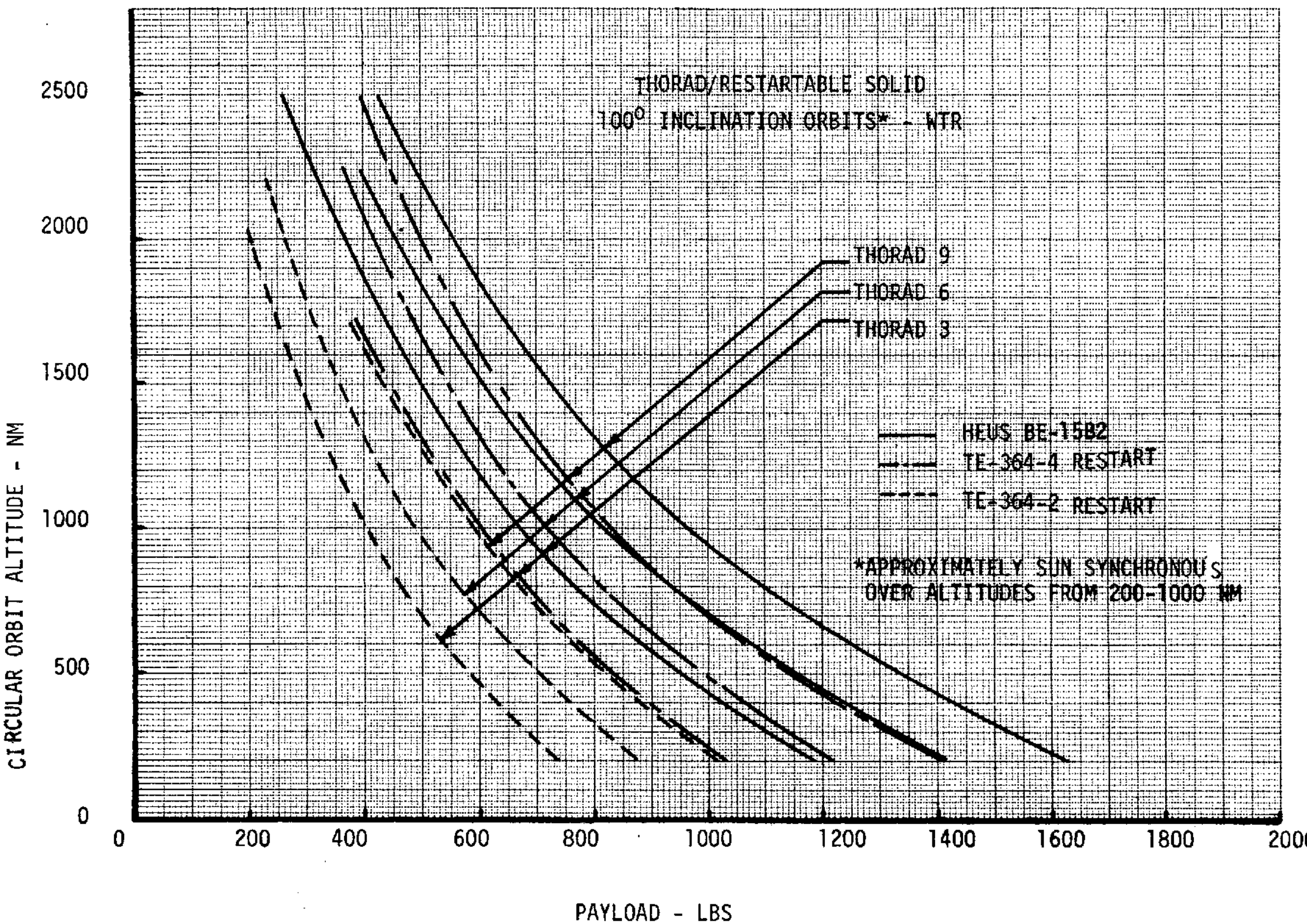

THORAD/RESTARTABLE SOLID
100° INCLINATION ORBITS* - WTR
THORAD 9
THORAD 6
THORAD 3
HEUS BE-15B2
TE-364-4 RESTART
TE-364-2 RESTART
*APPROXIMATELY SUN SYNCHRONOUS
OVER ALTITUDES FROM 200-1000 NM
CIRCULAR ORBIT ALTITUDE - NM
0
500
1000
1500
2000
2500
0
200
400
600
800
1000
1200
1400
1600
1800
2000
PAYLOAD - LBS

FIGURE 2.3-3

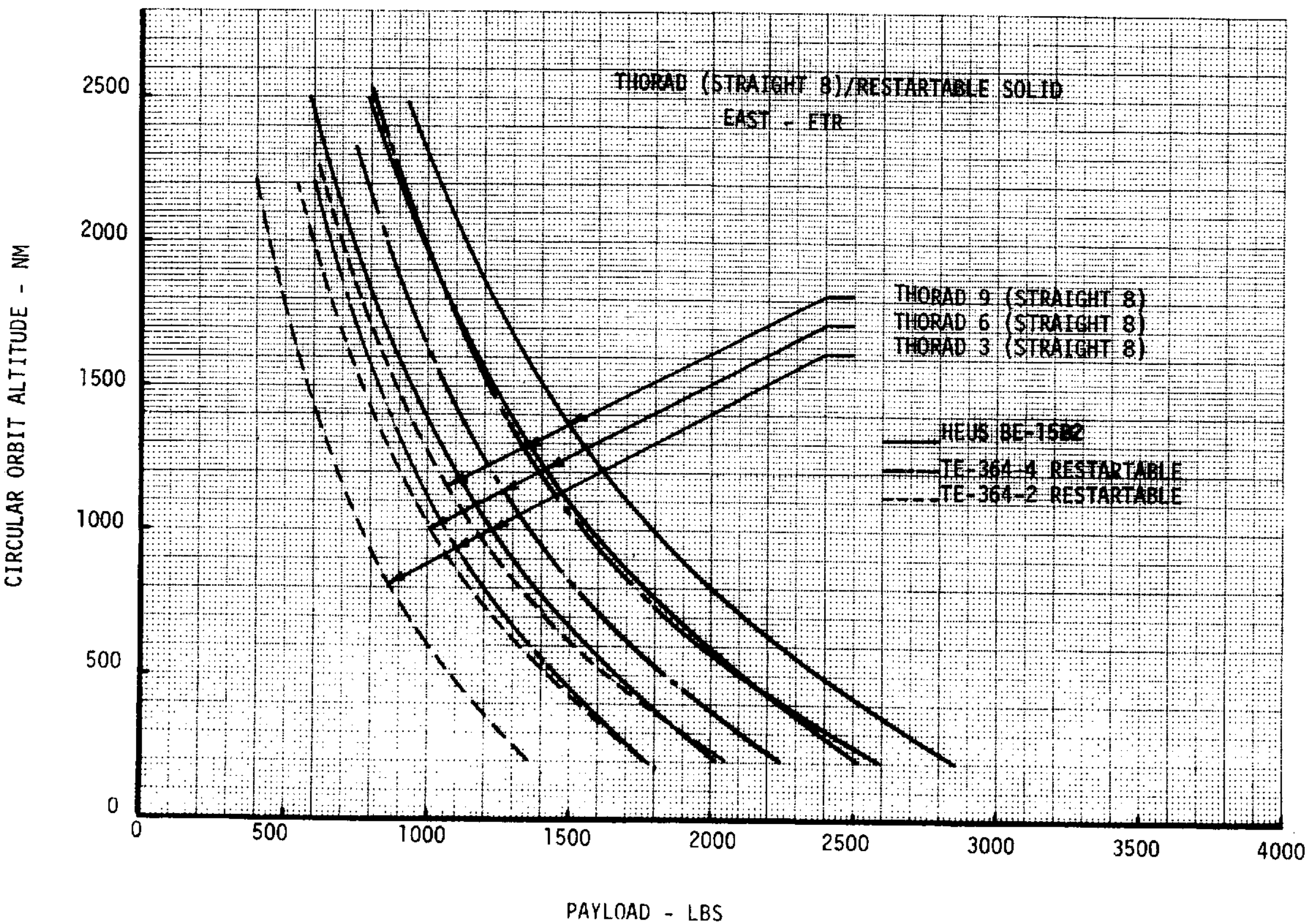

THORAD (STRAIGHT 8)/RESTARTABLE SOLID
EAST - ETR
THORAD 9 (STRAIGHT 8)
THORAD 6 (STRAIGHT 8)
THORAD 3 (STRAIGHT 8)
HEUS BE-15B2
TE-364-4 RESTARTABLE
TE-364-2 RESTARTABLE
CIRCULAR ORBIT ALTITUDE - NM
0
500
1000
1500
2000
2500
0
500
1000
1500
2000
2500
3000
3500
4000
PAYLOAD - LBS

FIGURE 2.3-4

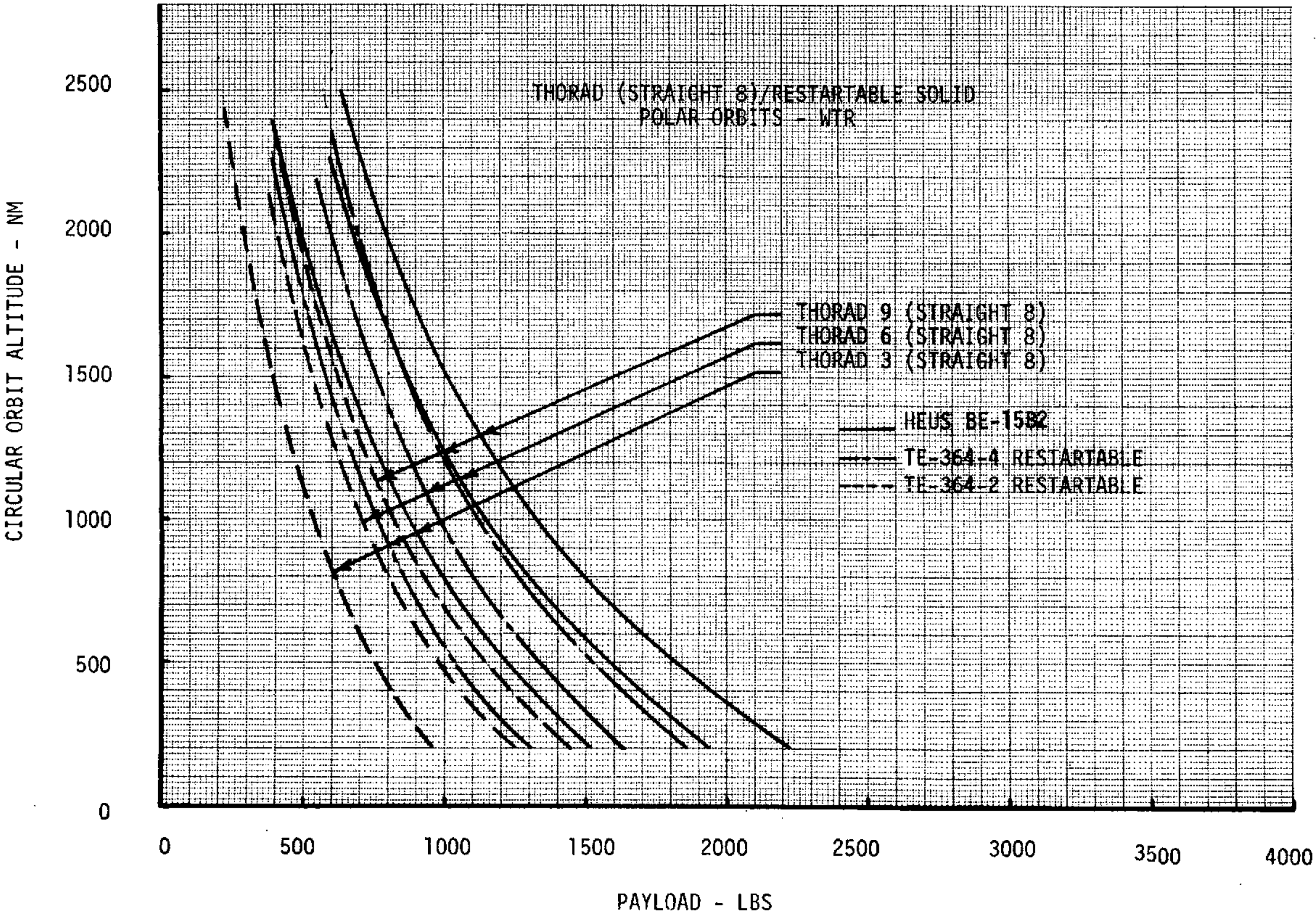
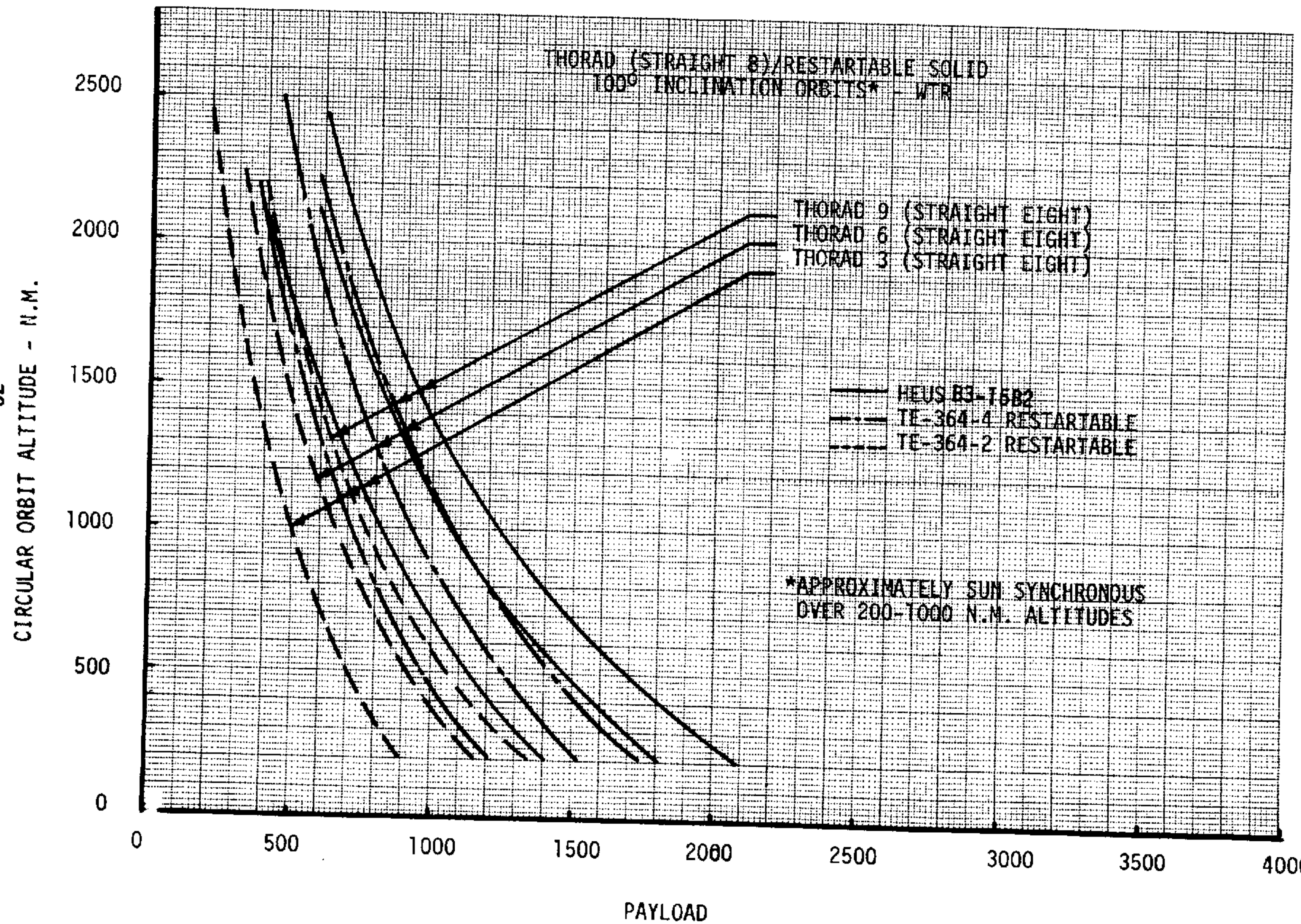

THORAD (STRAIGHT 8)/RESTARTABLE SOLID
POLAR ORBITS - WTR
THORAD 9 (STRAIGHT 8)
THORAD 6 (STRAIGHT 8)
THORAD 3 (STRAIGHT 8)
HEUS BE-15B2
TE-364-4 RESTARTABLE
TE-364-2 RESTARTABLE
CIRCULAR ORBIT ALTITUDE - NM
0
500
1000
1500
2000
2500
PAYLOAD - LBS
0
500
1000
1500
2000
2500
3000
3500
4000

FIGURE 2.3-5



THORAD (STRAIGHT 8)/RESTARTABLE SOLID
100° INCLINATION ORBITS* - WTR
THORAD 9 (STRAIGHT EIGHT)
THORAD 6 (STRAIGHT EIGHT)
THORAD 3 (STRAIGHT EIGHT)
HEUS B3-I6B2
TE-364-4 RESTARTABLE
TE-364-2 RESTARTABLE
*APPROXIMATELY SUN SYNCHRONOUS
OVER 200-1000 N.M. ALTITUDES
CIRCULAR ORBIT ALTITUDE - N.M.
2500
2000
1500
1000
500
0
0
500
1000
1500
2000
2500
3000
3500
4000
PAYLOAD

FIGURE 2.3-6

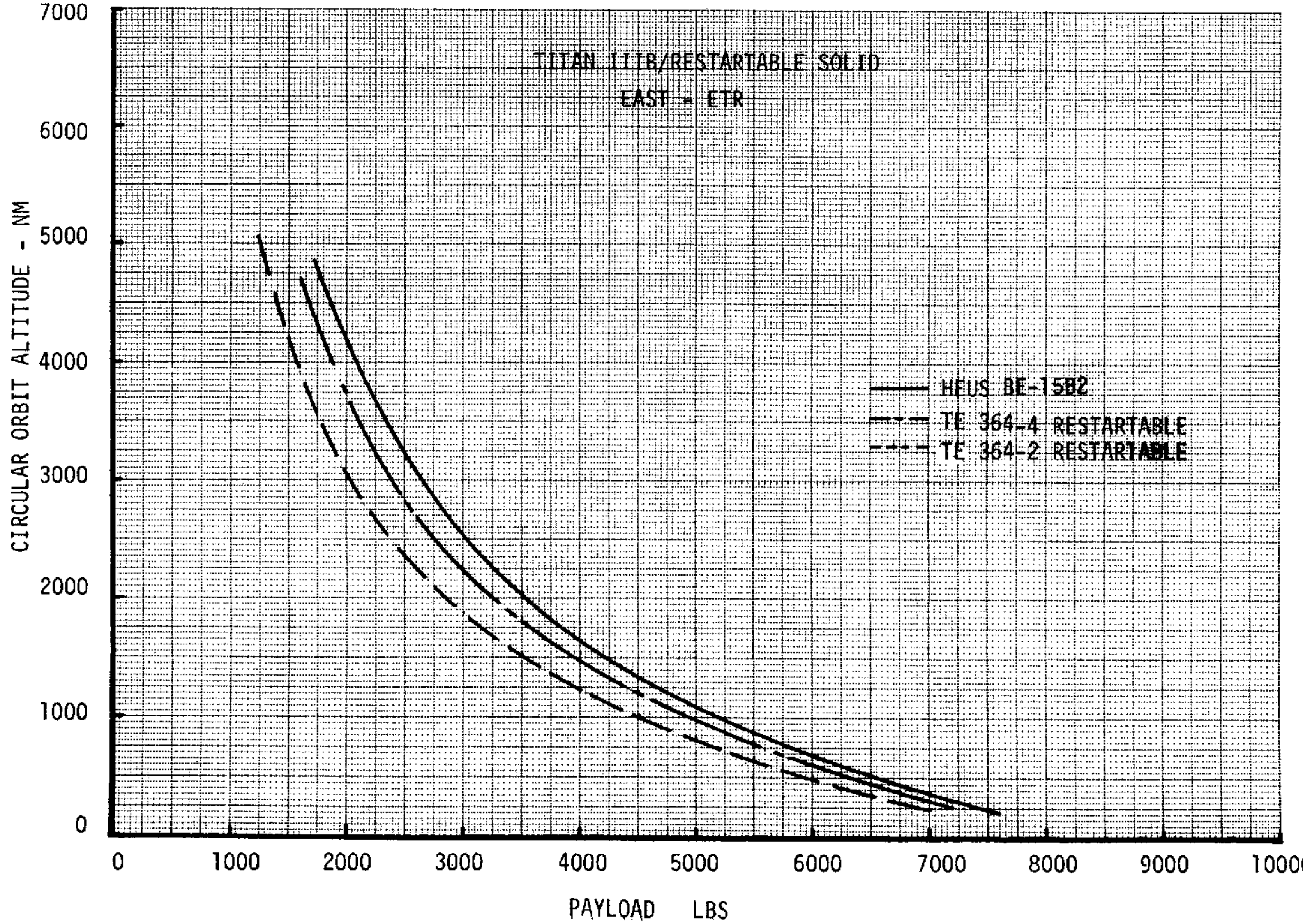

TITAN IIIB/RESTARTABLE SOLID
EAST - ETR
HEUS BE-15B2
TE 364-4 RESTARTABLE
TE 364-2 RESTARTABLE
CIRCULAR ORBIT ALTITUDE - NM
0
1000
2000
3000
4000
5000
6000
7000
8000
9000
10000
PAYLOAD LBS

FIGURE 2.3-7

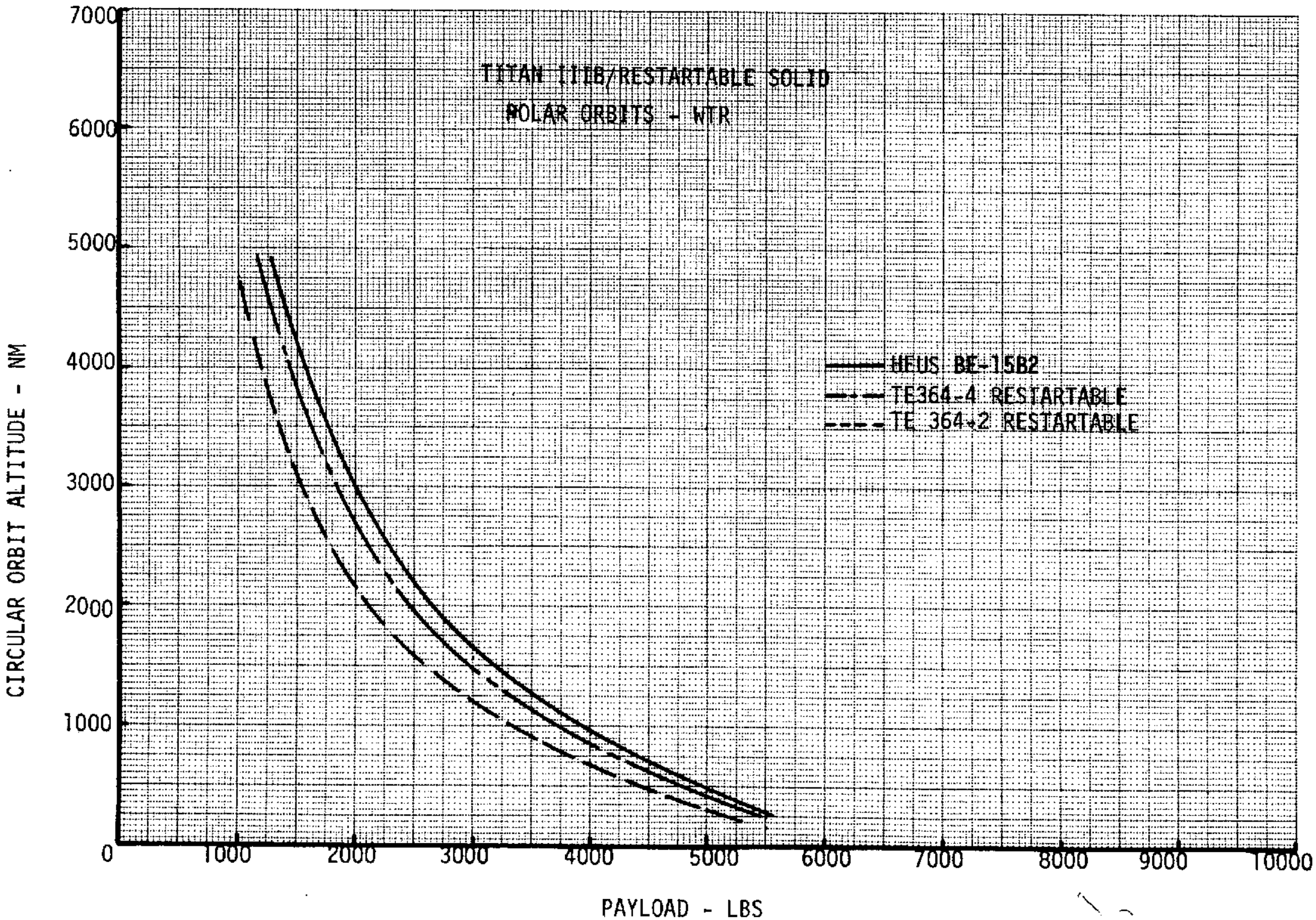
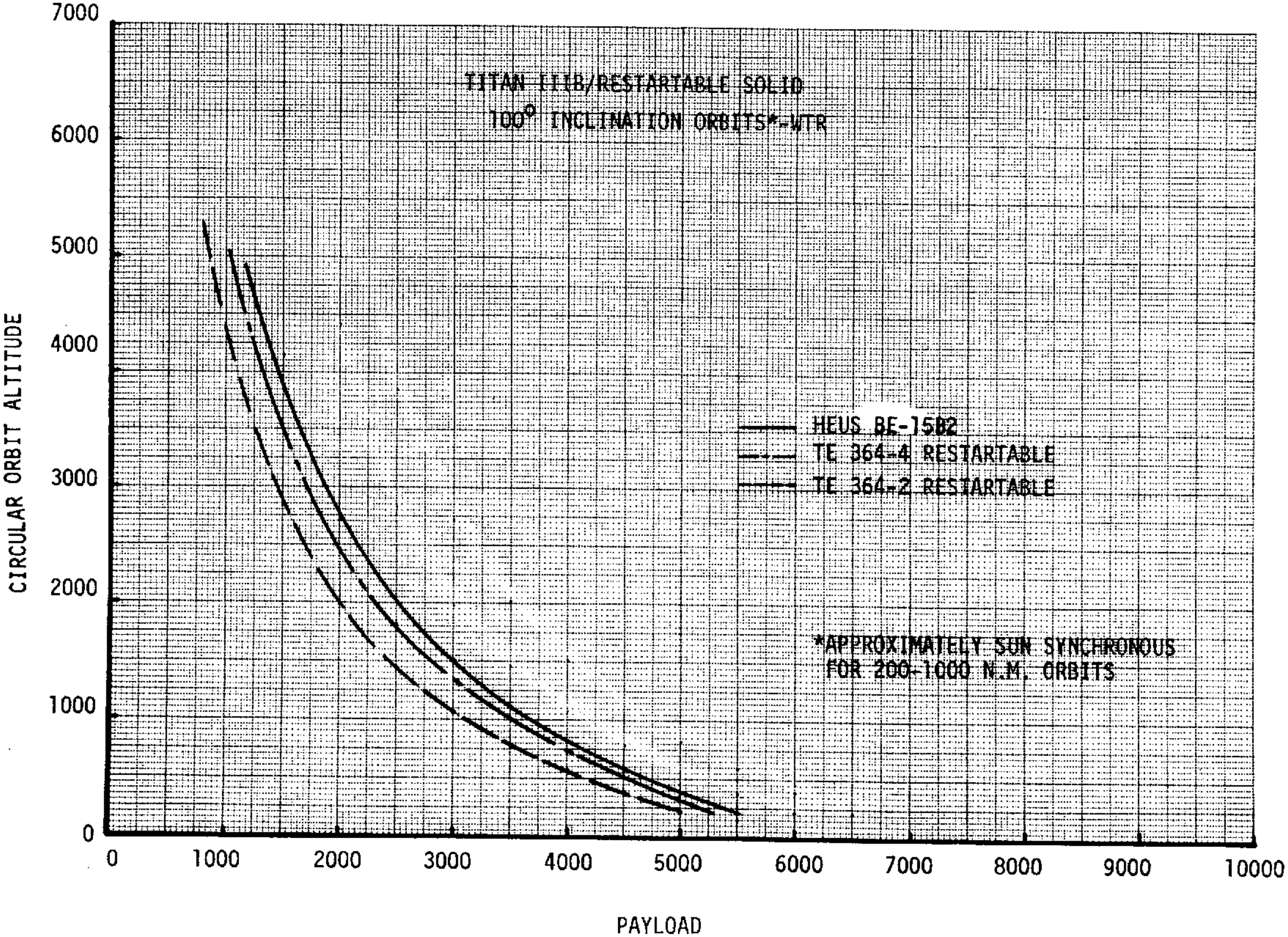

TITAN IIIB/RESTARTABLE SOLID
POLAR ORBITS - WTR
HEUS BE-15B2
TE364-4 RESTARTABLE
TE 364-2 RESTARTABLE
CIRCULAR ORBIT ALTITUDE - NM
7000
6000
5000
4000
3000
2000
1000
0
1000
2000
3000
4000
5000
6000
7000
8000
9000
10000
PAYLOAD - LBS

FIGURE 2.3-8



TITAN IIIB/RESTARTABLE SOLID
100° INCLINATION ORBITS*-WTR
HEUS BE-15B2
TE 364-4 RESTARTABLE
TE 364-2 RESTARTABLE
*APPROXIMATELY SUN SYNCHRONOUS
FOR 200-1000 N.M. ORBITS
CIRCULAR ORBIT ALTITUDE
PAYLOAD
0
1000
2000
3000
4000
5000
6000
7000
8000
9000
10000

FIGURE 2.3-9

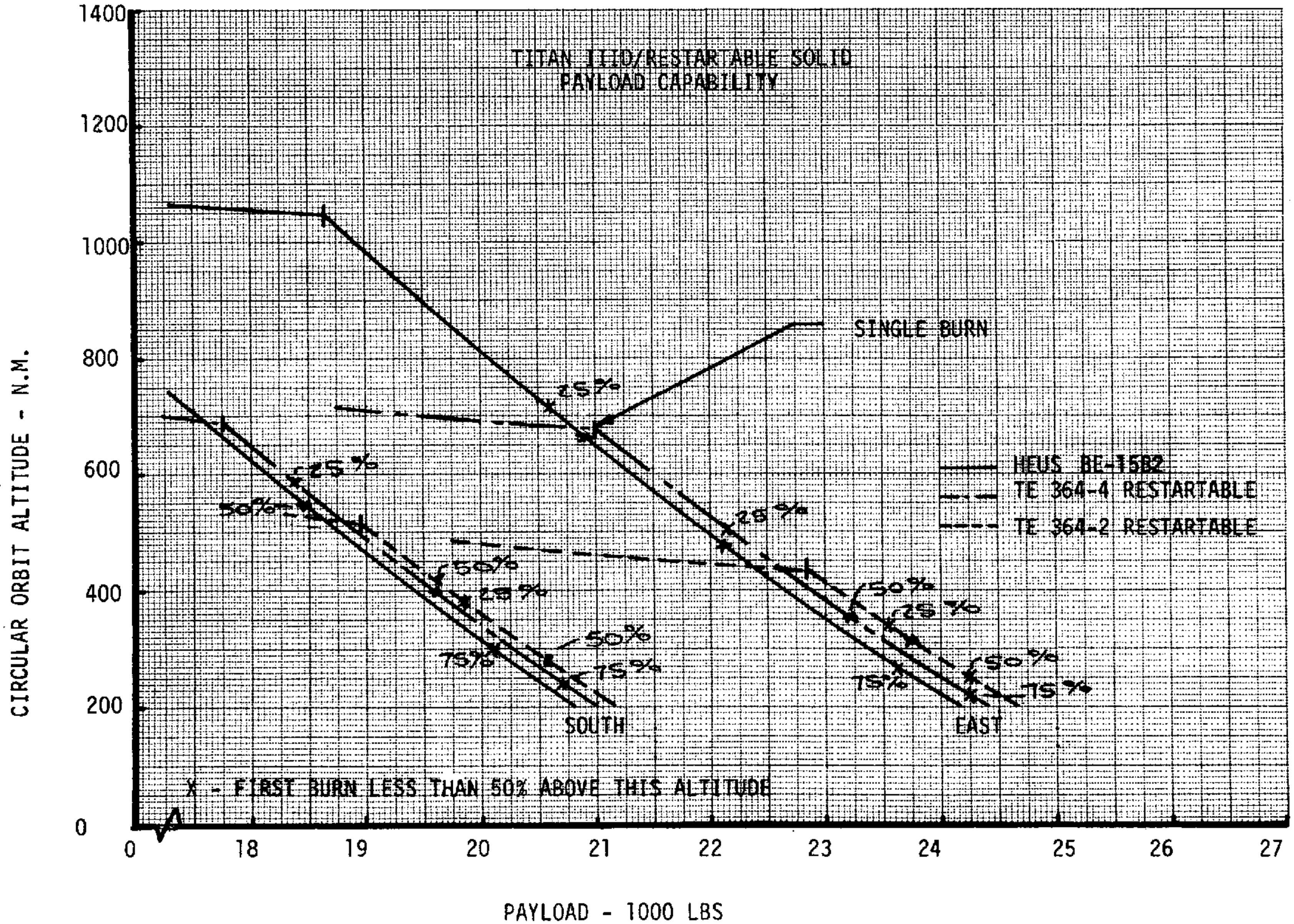

TITAN IIID/RESTARTABLE SOLID
PAYLOAD CAPABILITY
SINGLE BURN
HEUS RE-1582
TE 364-4 RESTARTABLE
TE 364-2 RESTARTABLE
25%
50%
75%
SOUTH
EAST
X - FIRST BURN LESS THAN 50% ABOVE THIS ALTITUDE
CIRCULAR ORBIT ALTITUDE - N.M.
0
200
400
600
800
1000
1200
1400
18
19
20
21
22
23
24
25
26
27
PAYLOAD - 1000 LBS

FIGURE 2.3-10

Two basic booster launch vehicle families were considered. The first includes the Titan IIID, Titan IIIB and the standard Thorad. An overall summary of the assignments made for each HEUS configuration is shown in Table 2.3-1. These data represent 35 low earth orbit type missions and 127 launches.

The second family replaces the standard Thorad with the "straight 8" Thorad. Table 2.3-2 shows the summary for this family.

Table 2.3-3 shows a comparitive summary of the two families indicating the number of mission types as well as the number of launches. These data indicate that no significant gain is attainable in this mission model using the BE-15B2 configuration. This effect tends to be biased by the mission model since there is a good overall performance gain with the BE-15B2 configuration.

Table 2.3-4 shows a detail breakdown of the vehicle assignments made on a mission by mission basis. Booster assignments are noted along with the payload capability for each HEUS configuration. Booster assignments were made based on using a lower cost vehicle than the existing assignment.

Although the mission model analysis demonstrates the value of a restartable solid the mission model tends to favor the current launch vehicle stable because assignments are made based on current launch vehicle capabilities. Table 2.3-5 shows the synchronous transfer capability of the Titan IIIB. While no missions appear in the mission model that are applicable to the Titan IIIB/HEUS, this vehicle provides an attractive gap filler for future mission requirements that exceed the TAT(9C)/DELTA/TE-M-364 capability and do not justify an Atlas/Centaur.

LAUNCH VEHICLE ASSIGNMENT

LOW EARTH ORBIT MISSIONS

		TITAN IIID			TITAN IIIB			THORAD 9 (STANDARD THORAD)			THORAD 6 (STANDARD THORAD)			THORAD 3 (STANDARD THORAD)			TOTALS		
		BE-15B2	364-4	364-2	BE-15B2	364-4	364-2	BE-15B2	364-4	364-2	BE-15B2	364-4	364-2	BE-15B2	364-4	364-2	BE-15B2	364-4	364-2
TITAN IIIC	9	9	9	9													9	9	9
ATLAS-CENTAUR	44				34	34	34										34	34	34
TITAN IIIB	0																		
DELTA 9	28							5	5	5							5	5	5
DELTA 6	9											6		6			6	6	
DELTA 3	37							5	1	1	1		3	28	28	24	34	29	28
TOTAL	127	9	9	9	34	34	34	10	6	6	1	6	3	34	28	24	88	83	76

TABLE 2.3-1

TABLE 2.3-1

LAUNCH VEHICLE ASSIGNMENT

LOW EARTH ORBIT MISSIONS

		TITAN III D			TITAN III B			THORAD 9 ("STRAIGHT 8" THORAD)			THORAD 6 ("STRAIGHT 8" THORAD)			THORAD 3 ("STRAIGHT 8" THORAD)			TOTALS		
		BE-15B2	364-4	364-2	BE-15B2	364-4	364-2	BE-15B2	364-4	364-2	BE-15B2	364-4	364-2	BE-15B2	364-4	364-2	BE-15B2	364-4	364-2
TITAN III C	9	9	9	9													9	9	9
ATLAS-CENTAUR	41				31	31	31										31	31	31
TITAN III B	0																		
DELTA 9	31							8	20	5	15						23	20	5
DELTA 6	9							1					6	6	6		7	6	6
DELTA 3	37									1	5	6	1	29	28	27	34	34	29
TOTAL	127	9	9	9	31	31	31	9	20	6	20	6	7	35	34	27	104	100	80

TABLE 2.3-2

TABLE 2.3-3

HEUS CONFIGURATION ASSIGNMENTS

FAMILY/CONFIGURATION	# TYPES OF MISSIONS	# OF LAUNCHES
MISSION MODEL TOTAL	35	127
<u>STANDARD THORAD</u>		
BE-15B2	28	88
TE-M-364-4	27	83
TE-M-364-2	25	76
<u>STRAIGHT 8</u>		
BE-15B2	30	104
TE-M-364-4	28	100
TE-M-364-2	26	80

MISSION ASSIGNMENTS TABLE 2.3-4

MISSION	PAYLOAD REQUIRED	CURRENT ASSIGNMENT	# LAUNCH	STANDARD THORAD BE-15B2 VEHICLE	PAYLOAD	STANDARD THORAD TE-M-364-4 VEHICLE	PAYLOAD	STANDARD THORAD TE-M-364-2 VEHICLE	PAYLOAD	"STRAIGHT 8" THORAD BE-15B2 VEHICLE	PAYLOAD	"STRAIGHT 8" THORAD TE-M-364-4 VEHICLE	PAYLOAD	"STRAIGHT 8" THORAD TE-M-364-2 VEHICLE	PAYLOAD
ESSA WORLD WEATHER WATCH	1800	ATLAS/CENTAUR	3	TITAN IIIB	4500	TITAN IIIB	4300	TITAN IIIB	3900	TITAN IIIB	4500	TITAN IIIB	4300	TITAN IIIB	3900
ESSA LOW	675	TAT(3C)/DELTA	1	TAT(3C)	820	TAT(3C)	730	TAT(9C)	710	TAT(3C)	990	TAT(3C)	850	TAT(6C)	850
ESSA LOW	1200	TAT(9C)/DELTA/ TE364	15							TAT(6C)	1390	TAT(9C)	1270		
ORBITAL SUPPORT	1000-3000	TAT(9C)/DELTA/ TE364	5	TAT(9C)	2200	TAT(9C)	1850	TAT(9C)	1420	TAT(9C)	2600	TAT(9C)	2350	TAT(9C)	1840
ORBITAL SUPPORT	3000-5000	ATLAS/CENTAUR	4	TITAN IIIB	7050	TITAN IIIB	6800	TITAN IIIB	6500	TITAN IIIB	7050	TITAN IIIB	6800	TITAN IIIB	6500
NIMBUS	1670	TAT(6C)/DELTA	1												
EOS TYPE (I)	2500	ATLAS/CENTAUR	3	TITAN IIIB	4700	TITAN IIIB	4500	TITAN IIIB	4150	TITAN IIIB	4700	TITAN IIIB	4500	TITAN IIIB	4150
EOS TYPE (II)	3800	ATLAS/CENTAUR	3	TITAN IIIB	4700	TITAN IIIB	4500	TITAN IIIB	4150	TITAN IIIB	4700	TITAN IIIB	4500	TITAN IIIB	4150
EOS TYPE (III)	7500	ATLAS/CENTAUR	10												
EPS -A	600	TAT(3C)/DELTA	1	TAT(3C)	1320	TAT(3C)	1210	TAT(3C)	820	TAT(3C)	1560	TAT(3C)	1560	TAT(3C)	1000
EPS -B	600	TAT(3C)/DELTA	1	TAT(3C)/	1140	TAT(3C)	1090	TAT(3C)	650	TAT(3C)	1360	TAT(3C)	1150	TAT(8C)	850
TIROS O	1500	ATLAS/CENT(STD) TAT(3C)/DELTA(ST8)	3	TITAN IIIB	4280	TITAN IIIB	4050	TITAN IIIB	3650	TAT(9C)	1500				
TIROS N	1000	TAT(3C)/DELTA	1	TAT(6C)	1000	TAT(9C)	1000			TAT(3C)	1000	TAT(6C)	1110	TAT(9C)	1000
POLAR-ERS	2500	ATLAS/CENTAUR	4	TITAN IIIB	4700	TITAN IIIB	4500	TITAN IIIB	4150	TITAN IIIB	4700	TITAN IIIB	4500	TITAN IIIB	4150
MULTI-DISCIP EARTH OBS.	2500	ATLAS/CENTAUR	10	TITAN IIIB	4700	TITAN IIIB	4500	TITAN IIIB	4150	TITAN IIIB	4700	TITAN IIIB	4500	TITAN IIIB	4150
SEA SAT	400	TAT(3C)/DELTA	1	TAT(3C)	1100	TAT(3C)	950	TAT(3C)	680	TAT(3C)	1310	TAT(3C)	1110	TAT(3C)	800
MAGNETIC SURVEY SAT	600	TAT(3C)/DELTA	4	TAT(3C)	1275	TAT(3C	1090	TAT(3C)	790	TAT(3C)	1510	TAT(3C)	1310	TAT(3C)	950
LARGE SOLAR OBS.	22000	TITAN IIIC	1	TITAN IIID	23000	TITAN IIID	23250	TITAN IIID	23500	TITAN IIID	23000	TITAN IIID	23250	TITAN IIID	23500
LARGE RADIO OBS.	22000	TITAN IIIC	1	TITAN IIID	23795	TITAN IIID	24000	TITAN IIID	24250	TITAN IIID	23795	TITAN IIID	24000	TITAN IIID	24250
LST	22000	TITAN IIIC	1	TITAN IIID	23430	TITAN IIID	23600	TITAN IIID	23850	TITAN IIID	23430	TITAN IIID	23600	TITAN IIID	23850
LST	30000	TITAN 7 IIIC	1	TITAN$_7$ IIID	34140	TITAN$_7$ IIID	34300	TITAN$_7$ IIID	34410	TITAN$_7$ IIID	34140	TITAN$_7$ IIID	34300	TITAN$_7$ IIID	34410
HEAD	21000	TITAN IIIC	4	TITAN IIID	24500	TITAN IIID	24400	TITAN IIID	24590	TITAN IIID	24200	TITAN IIID	24000	TITAN IIID	24690
HIGH ENERGY COSMIC LAB.	30000	TITAN$_7$ IIIC	1	TITAN$_7$ IIID	33540	TITAN$_7$ IIID	33700	TITAN$_7$ IIID	30000	TITAN$_7$ IIID	33540	TITAN$_7$ IIID	33700	TITAN$_7$ IIID	30000
OSO I-M	2000	TAT(3C)/DELTA	5	TAT(9C)	2200					TAT(6C)	2420	TAT(6C)	2100		
ASTRONOMY EXPLORER B	1000	TAT(3C)/DELTA	6	TAT(3C)	1560	TAT(3C)	1335	TAT(3C)	1020	TAT(3C)	1840	TAT(3C)	1610	TAT(3C)	1200

FOLDOUT FRAME

2

MISSION ASSIGNMENTS TABLE 2.2-4 CONT'D

				STANDARD THORAD						"STRAIGHT 8" THORAD					
				BE-15B2		TE-M-364-4		TE-M-364-2		BE-15B2		TE-M-364-4		TE-M-364-2	
MISSION	PAYLOAD REQUIRED	CURRENT ASSIGNMENT	# LAUNCH	VEHICLE	PAYLOAD	VEHICLE	PAYLOAD	VEHICLE	PAYLOAD	VEHICLE	PAYLOAD	VEHICLE	PAYLOAD	VEHICLE	PAYLOAD
LOWER MAGNETOSPHERE	1000	TAT(6C)/DELTA /TE364	6	TAT(3C)	1100	TAT(6C)	1140			TAT(3C)	1300	TAT(3C)	1120	TAT(6C)	1070
ATMOSPHERE EXPLORER -D	1000	TAT(6C)/DELTA	1							TAT(9C)	1000				
ATMOSPHERE EXPLORER -E	1000	TAT(6C)/DELTA	1												
RELATIVITY B-D	2000	TAT(3C)/DELTA/ TE364	3												
GRAVITY/RELATIVITY A,cC, E	500	TAT(3C)/DELTA	3	TAT(3C)	1080	TAT(3C)	1020	TAT(3C)	735	TAT(3C)	1410	TAT(3C)	1200	TAT(3C)	880
PHYSICS EXPLORER	600	TAT(3C)/DELTA	825	TAT(3C)	828	TAT(6C)	630	TAT(3C)	6380	TAT(3C)	8580	TAT(3C)	850	TAT(3C)	600
EARTH RESOURCES SURVEY	2000	TAT(9C)/DELTA													
OAO -D	4660	ATLAS/CENTAUR	1	TITAN IIIB	6900	TITAN IIIB	6650	TITAN IIIB	6300	TITAN IIIB	6900	TITAN IIIB	6650	TITAN IIIB	6300
OAO -E-G	6000	ATLAS/CENTAUR	3	TITAN IIIB	6900	TITAN IIIB	6650	TITAN IIIB	6300	TITAN IIIB	6900	TITAN IIIB	6650	TITAN IIIB	6300
SATS	600	TAT(3C)/DELTA	8	TAT(3C)	1185	TAT(3C)	1020	TAT(3C)	735	TAT(3C)	1410	TAT(3C)	1200	TAT(3C)	880

FOLDOUT FRAME 1

FOLDOUT FRAME 2

TABLE 2.3-5

SYNCHRONOUS TRANSFER ORBIT

CAPABILITY - TITAN IIIB

UPPER STAGE MOTOR	PAYLOAD
BE-15B2	1900
TE-364-4	1700
TE-364-2	1440

2.3.3 Program R.O.M. Cost

The total HEUS-RS launch program ROM Cost is contained in Volume II.

2.3.4 HEUS-RS Development and Qualification Costs

The ROM cost for development and qualification of the HEUS-RS including launch vehicle and launch site integration is contained in Volume II.

2.4 TASK 4 - ALTERNATE LAUNCH PROGRAM

2.4.1 Task Requirement

An alternate approach to meeting the mission model was required. The mission model requirements generated in Task 1 required review and concepts defined for performing the missions without the HEUS-RS restart capability.

2.4.2 Alternate Launch Program Costs

The alternate launch program costs are contained in Volume II.

2.5 TASK 5 - PROGRAM COMPARISON

2.5.1 Task Requirement

The HEUS-RS launch program costs developed in Task 3 and the alternate launch program costs developed in Task 4 were compared and the costs are contained in Volume II.

2.6 HEUS/BII SHUTTLE APPLICATION

2.6.1 Task Requirement

This task is to define the shuttle application of the HEUS configuration in terms of payload capability.

2.6.2 HEUS/BII Shuttle Performance

The HEUS configurations were evaluated for use as an interim tug for space shuttle applications. General payload data has been defined as shown in Figure 2.6-1. These data show the capability of the HEUS to given mission altitudes as a function of inclination changes. The host orbits for the shuttle are assumed to be 100 nm inclined at 28.5°, 55° and polar. These inclinations require some inclination changes to meet mission model requirements.

Table 2.6-I shows a summary of the HEUS configurations capability to meet the mission model requirements. These data assume no maneuver capability in the shuttle and all mission requirements must be met by the HEUS.

The mission model used represents the 1981-1990 portion of the mission model presented in section 2.1.1. The summary shows that the HEUS-BE-15B2 configuration can meet the requirements for 63 of the 75 missions. The mission model shows that the 12 missions outside the HEUS capability represent 3 mission types. One 10 launch program and two single launch programs.

Table 2.6-II shows a detailed breakdown of the mission model and the HEUS configuration assignments. In several cases the HEUS capability exceeds the requirement by a large factor. These missions can be designed to meet the payload requirements desired. The data shown reflects only the maximum capability.

Virtually all shuttle application missions fall in the 40% to 60% first burn regime. This requirement may precipitate minor modifications in the restartable solid motor design for shuttle applications.

Consideration was given to synchronous equatorial applications of the HEUS configurations. Figure 2.6-2 shows the synchronous equatorial capability as a function of propellant weight. These data indicate that a larger propellant weight motor than the BE-15B2 is required in order to provide a reasonable capability for these missions.

An alternative to a larger propellant weight motor would be two stage configurations. Since these applications require only one restart, the tandem configuration would include one restartable and one single burn motor. The restartable motor would be placed in the stack as required to meet the mission objectives. For instance, in the synchronous equatorial application, the perigee burn would require the complete burn of the lower stage and a partial burn of the upper stage. Apogee injection would then be provided by a second burn of the upper stage motor.

The HEUS configurations do provide an attractive capability for shuttle applications. However, a more detailed study is required to verify the validity and compatibility of the HEUS with shuttle operations.

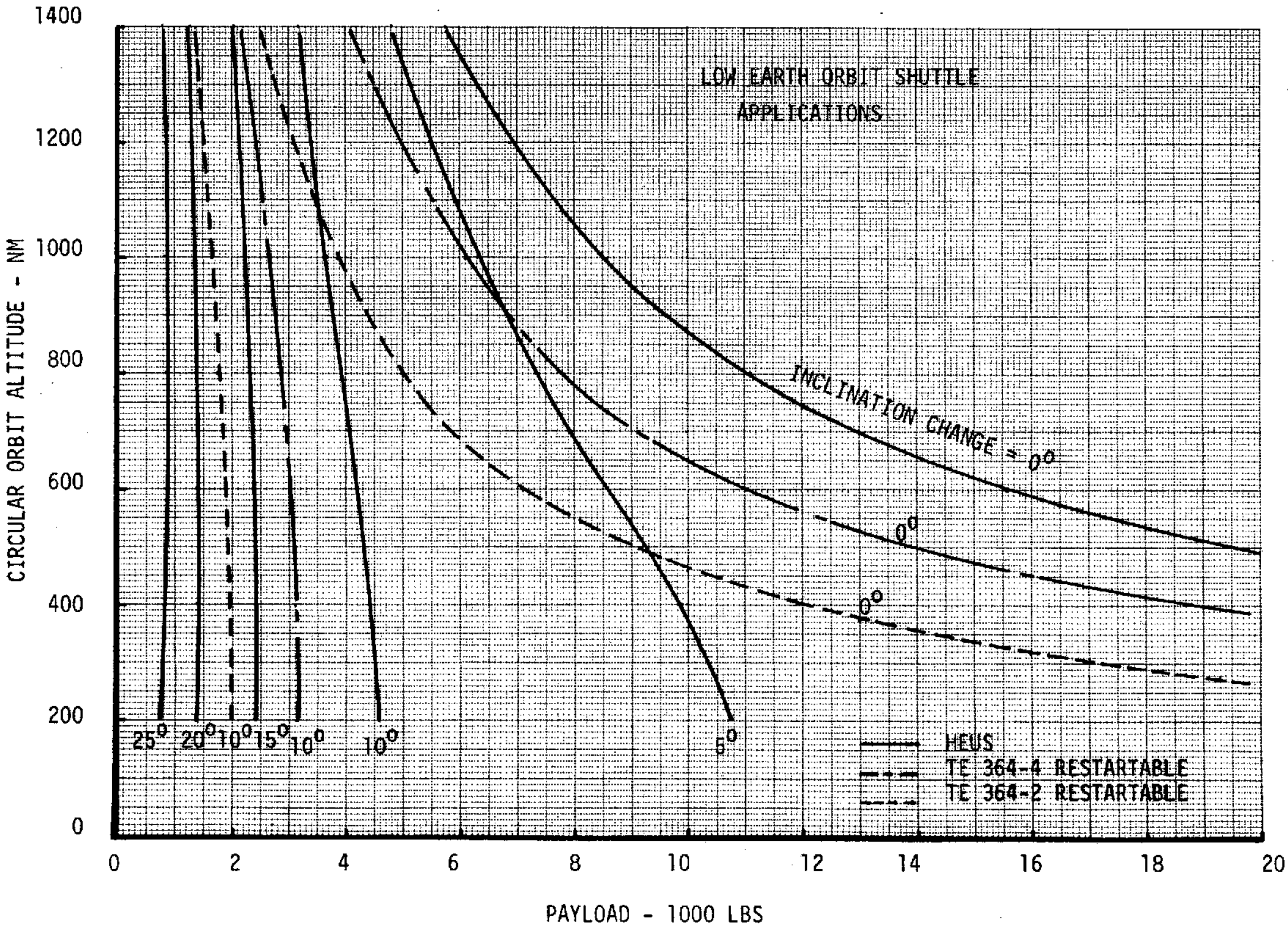

LOW EARTH ORBIT SHUTTLE
APPLICATIONS
CIRCULAR ORBIT ALTITUDE - NM
0
200
400
600
800
1000
1200
1400
PAYLOAD - 1000 LBS
0
2
4
6
8
10
12
14
16
18
20
INCLINATION CHANGE = 0°
0°
0°
25°
20°
10°
15°
10°
10°
5°
HEUS
TE 364-4 RESTARTABLE
TE 364-2 RESTARTABLE

FIGURE 2.6-1

TABLE 2.6-I

POST 1981 SHUTTLE MISSIONS

CURRENT LAUNCH VEH.		BE-15B2	TE364-4	TE-364-2	TOTAL
TITAN IIIC	6	1	2	1	4
ATLAS/CENTAUR	24		7	7	14
TAT(9C)/DELTA	20			20	20
TAT(6C)/DELTA	5			5	5
TAT(3C)/DELTA	20			20	20
TOTAL	75	1	9	53	63

ASSIGNMENTS BASED ON SMALLEST STAGE REQUIRED

HENCE:	TE-364-2	53 MISSIONS
	TE 364-4	62 MISSIONS
	BE-15B2	63 MISSIONS

SHUTTLE APPLICATION
TABLE 2.6-II

MISSION	81	82	83	84	85	86	87	88	89	90	WEIGHT	AP	PERL	INCL	BE-15B2	TE364-4	TE364-2	TOTAL MISSIONS	LAUNCH VEHICLE
ESSA LOW	1	1	1	1	1	1	1	1	1	1	1200	700	700	101°	4100	2900	1850	10	TAT(9C)/DELTA /TE364
ORBITAL SUPPORT		1		1		1		1		1	1000-3000	350	350	28.5	30000	22000	14300	5	TAT(9C)/DELTA /TE364
ORBITAL SUPPORT			1		1		1		1		3000-5000	350	350	28.5	30000	22000	14300	4	ATLAS/CENTAUR
EOS (TYPE III)	1	1	1	1	1	1	1	1	1	1	7500	500	500	99°				10	ATLAS/CENTAUR
EIROS O	1				1					1	1500	700	700	101°	4100	2900	1850	3	ATLAS/CENTAUR
MULTI-DISCIP EARTH OBS	1		1	1		1	1		1	1	2500	500	500	99°	4300	3100		7	ATLAS/CENTAUR
MAGNETIC SURVEY SAT			1		1		1		1		400	400	400	90°	26230	18850	12000	4	TAT(3C)/DELTA
LARGE SOLAR OBSERV			1								22000	350	350	28.5	30000	22000		1	TITAN IIIC
LARGE RADIO OBSERV					1						22000	250	250	28.5	67000	48000		1	TITAN IIIC
LST	1										22000	300	300	33°				1	TITAN IIIC
LST					1						30000	300	300	33°				1	TITAN IIIC
HEAO	1										21000	200	200	28.5	80000	57100	36830	1	TITAN IIIC
HIGH ENERGY COSMIC LAB								1			30000	350	350	28.5	30000			1	TITAN IIIC
OSO M		1									2000	300	300	28.5	32000	26000	22000	1	TAT(3C)/DELTA
ASTRONOMY EXPL.	1		1		1				1		1000	350	350	28.5	30000	22000	14300	4	TAT(3C)/DELTA
LOWER MAGNETOSPHERE	1		1		1		1		1		1000	900	900	28.5	9600	6800	4400	5	TAT(6C)/DELTA /TE364
RELATIVITY B-D			1				1			1	2000	430	430	90°	21500	17100	11000	3	TAT(3C)/DELTA /36V
RELATIVITY A, C, E				1						1	500	300	300	90°	32000	26000	22000	2	TAT(3C)/DELTA
PHYSICS EXPL	1										600	800	800	90°	11000	7800	5000	1	TAT(3C)/DELTA
EARTH RESOURCES SURVEY	1		1		1		1		1		2000	300	300	98°	4500	3150	2050	5	TAT(9C)/DELTA
SATS		1		1		1		1		1	600	300	300	90°	32000	26000	11000	5	TAT(3C)/DELTA
																		73	

FOLDOUT FRAME

FOLDOUT FRAME 2

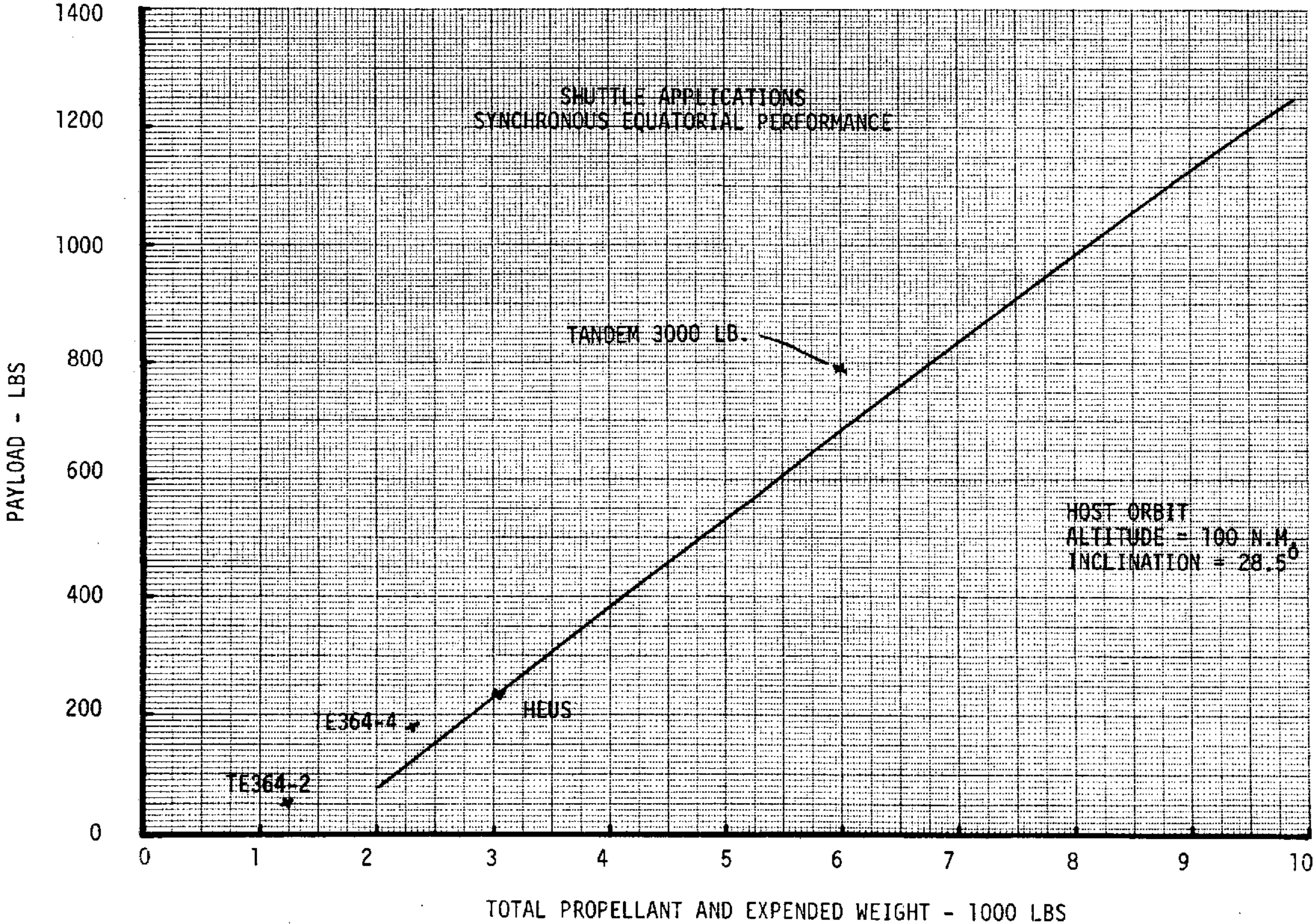

SHUTTLE APPLICATIONS
SYNCHRONOUS EQUATORIAL PERFORMANCE
PAYLOAD - LBS
1400
1200
1000
800
600
400
200
0
TANDEM 3000 LB.
HEUS
TE364-4
TE364-2
HOST ORBIT
ALTITUDE = 100 N.M.
INCLINATION = 28.5°
0
1
2
3
4
5
6
7
8
9
10
TOTAL PROPELLANT AND EXPENDED WEIGHT - 1000 LBS

FIGURE 2.6-2

3.0 REFERENCES

1. 2-1109-3600-570, HEUS Study Status Report for October 1971, dated 4 November 1971

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5. Report No. H250-12-6-7, July 1970, Final Report, Phase II, High Energy Upper Stage Motor Program. Volume 1 through IV, Prepared by Hercules Incorporated, Wilmington, Delaware

6. NHB 7100.5 NASA Launch Vehicle Estimating Factors Handbook, January 1971 Edition

7. NHB 7100.5A NASA Launch Vehicle Estimating Factor Handbook, January 1972 Edition